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ABSTRACT

This module is the tenth in a series of eleven modules in an energy conservation curriculum for secondary and postsecondary vocational students. It is designed for use by itself or as part of a sequence of four modules on energy conservation in building construction and operation (see also modules 8, 9, and 11). The objective of this module is to train students in the recognition, implementation, and utilization of energy consumption and possible conservation in heating, ventilating, and air conditioning. First, an introduction to the module and definitions of key terms are provided. Next, the text is presented in the following four units: (1) fundamentals of heating and cooling; (2) heating systems; (3) cooling systems; and (4) duct work. The information in each unit is presented in lecture format accompanied by laboratory exercises and questions/examples for class discussion. A bibliography and several charts illustrating the text material are found at the end of the module. (BM)

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Energy Conservation Curriculum for Secondary and Post-Secondary Vocational Students. Module 10.

HEATING, VENTILATING, AND AIR CONDITIONING CONSERVATION OPPORTUNITIES

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NAVARRO COLLEGE
CORSICANA, TEXAS

April, 1979

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MODULE #10

HEATING, VENTILATING, AND AIR CONDITIONING CONSERVATION OPPORTUNITIES

This module is one of a group of 11 modules in an energy conservation curriculum for secondary and post-secondary vocational students. Heating, Ventilating, and Air Conditioning Conservation Opportunities may be offered by itself or as part of a sequence of 3 modules in the following order:

Order	Module	Title of Module
1	9	Human Comfort and Energy Conservation
2	8	Building Construction vs Energy Consumption
3	10	Heating, Ventilating, and Air Conditioning Conservation Opportunities

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MODULE #10

HEATING, VENTILATING, AND AIR CONDITIONING CONSERVATION OPPORTUNITIES

MODULE DESCRIPTION:

This module discusses the principles of heating and cooling in buildings such as heat loss, heat gain, heating loads, and cooling loads. Heating load and cooling load characteristics for sizing home heating and cooling equipment requirements are discussed in terms of relative humidity and summer and winter design temperatures.

Heating and cooling equipment are presented in terms of components of operation, energy efficiency ratings, and equipment energy usage and design. Ductwork is explored as the delivery system of home conditioned air. Cost/benefit analysis of energy conservation opportunities in heating, ventilating, and air conditioning are explored in the areas of equipment operation, maintenance, and control.

GOAL STATEMENT:

The objective of this module is to train secondary and post-secondary students in the recognition, implementation, and utilization of energy consumption and possible conservation in heating, ventilating, and air conditioning.

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MODULE #10

HEATING, VENTILATING, AND AIR CONDITIONING
CONSERVATION OPPORTUNITIES

TERMINOLOGY

Absorption - a process whereby heat extracts one or more substances present in an atmosphere or mixture of gases or liquids, accompanied by physical change, chemical change, or both changes of the material.

Absorption Chiller - a refrigeration unit based upon absorption refrigeration.

Absorption refrigeration - cooling which is effected by the expansion of liquid ammonia into gas by water. Heat is the primary source of energy.

Active - when applied to building design, it refers to the mechanical movement of energy by the use of an external force of energy.

Air change - the movement of a volume of air in a given period of time; if a house has one air change per hour, it means that all the air in the house will be replaced in a one-hour period. Air changes are expressed in cubic feet per minute.

Air conditioning - the process of treating air to control its temperature, humidity, flow, and odor.

Ambient temperature - temperature of the outside air.

Attic ventilation - in houses, screened openings provided to ventilate an attic space. They are located in the soffit area as inlet ventilators and in the gable end or along the ridge as outlet ventilators. They can also consist of powerdriven fans used as an exhaust system.

Berm - a mound or small hill of earth, man-made.

British Thermal Unit (BTU) - the amount of heat necessary to raise the temperature of one pound of water one degree Fahrenheit; a unit of heat roughly equal to the amount of heat given off by burning a kitchen match.

Building skin - the physical structure which encloses a building.

Bypass loop - a piping arrangement which bypasses or circles the flow of a heat absorbing medium around rather than through a piece of mechanical equipment.

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CFM - an abbreviation for cubic feet per minute.

Capacity - the usuable output of a system.

Centrified fan - a machine for moving a gas, such as air, by accelerating it rapidly outward in an impeller to a surrounding casing; generally of a scroll shape.

Change of state (phase change) - the change from solid, or gas to either of the other two.

Chimney effect - the tendency of air or gas in a duct or other vertical passage to rise when heated due to its lower density compared with that of the surrounding air or gas. In buildings, the tendency toward displacement (caused by the difference in temperature) of internal heated air by unheated outside air due to the difference in density of outside and inside air.

Coil - a cooling or heating element made of pipe or tubing.

Comfort zone - the ranges of indoor temperature, humidity, and air movement under which most persons enjoy mental and physical well-being.

Compression - in a compression refrigeration system, a process by which the pressure and temperature of the refrigerant is increased to allow for greater heat transfer.

Conduction - a process of heat transfer whereby heat moves through a material.

Convection - transfer of heat by movement of a fluid or gas.

Crack method - a method used in the calculation of air movement from the outside into an enclosed space. The method is based on the rate through one foot of crack between sash and frame or between door and frame.

DHW tank - abbreviated form for Domestic Hot Water tank.

Damper - a device used to vary the volume of air passing through an air outlet, inlet or duct.

Dehumidification - the condensation of water vapor from air by cooling below the dew point or removal of water vapor from air by chemical or physical methods.

Density - the weight per unit volume.

Diurnal cycle - the day-to-night change or cycle of natural phenomenon. An example is the variation of outdoor temperature throughout a twenty-four hour period.

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Dry bulb temperature - a measure of the sensible temperature of air (the one with which we are most familiar).

Economizer cycle - a cooling mode which uses cool outdoor air to offset heat gains in buildings rather than using an energy consuming cooling device.

Electronic air filter - the use of electricity to set up a static charge which can remove dust and other particulate matter.

Energy - the capacity for doing work; taking a number of forms which may be transformed from one into another, such as thermal (heat), mechanical (work), electrical and chemical; in customary units, measured in kilowatt hours (KWH) or British Thermal Units (BTU); in SI units, measured in joules (J), where 1 joule = 1 watt-second.

Enthalph - a measurement of the total energy content of the air. The total energy content is composed of both sensible and latent heat as measured by the dry bulb and wet bulb temperatures.

Evaporative cooling - lowering the temperature of a large mass of liquid by utilizing the latent heat of vaporization of a portion of the liquid; cooling air by evaporating water into it.

Flow rate - velocity at which a fluid travels, usually through an opening or duct.

Frequency of occurrence - the number of times a given event will occur during a given period of time.

GPM - an abbreviation for gallons per minute.

Greenhouse effect - the effect of the earth's atmosphere in trapping heat from the sun. The atmosphere acts like a greenhouse by admitting the sun's shortwave radiation but blocking the exit of long wavelength radiation re-emitted by the earth or other warned objects.

Heat capacity - sometimes called the thermal capacity, a measure of how much heat is required to raise the temperature of a specific quantity of material by a given amount.

Heat dissipator - the method of transmitting energy or power out of a system in the form of heat.

Heat exchanger - a device used to transfer heat from one medium to the other.

Heat gain - an increase in the amount of heat contained in a space, resulting from direct solar radiation and the heat given off by people, lights, equipment, machinery, and other sources.

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Heat loss - a decrease in the amount of heat contained in a space, resulting from heat flow through walls, windows, roof, and other building envelope components.

Heat pump - a reversible refrigeration system that delivers more heat energy to the end use than is put in to the compressor. The additional energy input results from the absorption of heat from a low temperature source--the combination heating and cooling unit. It operates like a normal air conditioner in summer, and in winter operates in reverse, ejecting warm air indoors and cool air (or water) outdoors.

Heat wheel - a device used in ventilating systems which tends to bring incoming air into thermal equilibrium with existing air. As a result, hot summer air is cooled and cold winter air is warmed.

Humidifier - a device to add moisture to air.

In-line pump - a pump which is supported by the piping system.

Incident - usually used in the term "incident radiation" which is the amount of energy striking a collector surface before entering the collector.

Infiltration - the uncontrolled flow of air into and out of a building through cracks, openings, doors, or other areas which allow air to penetrate.

Initial cost - the original price of an item or system.

Insulation, thermal - any material high in resistance to heat transmission that, when placed in the walls, ceilings, or floors of a structure, will reduce the rate of heat flow.

Kilowatt Hour (KWH) - unit of electrical energy consumption which equals about 3,400 BTU.

Latent heat - a change in heat content that occurs without a corresponding change in temperaure, usually accompanied by a change of state.

Peak load - maximum predicted energy demand of a system.

Perms-permeance - the ratio of water vapor flow to the vapor pressure difference of the surfaces; permeance is expressed in perms or (grains)/(Sq.Ft.)(Hr,), and of mercury vapor pressure difference.

Psychrometric - pertaining to the device comprising two thermometers, one a dry bulb, the other a wet bulb or wick-covered bulb, used in determining the moisture content or relative humidity of air or other gases.

R-value resistance - the resistance of a material to the flow of heat or energy.

Reflectance - a property of a material indicating the percentage of light that is reflected when a certain amount of light strikes the surface of the material or is transmitted through it.

Relative humidity - the ratio of the amount of water vapor at a given temperature to the maximum amount of water vapor that could be held as vapor.

Sensible heat - heat that results in a temperature change.

Set back - the lowering of the thermostat setting. The technique is used to reduce the amount of heat required to heat a space.

Set up - the raising of the thermostat setting. The technique is used to reduce the amount of cooling required to cool a space.

Shortwave radiation - a term used loosely to distinguish radiation in the visible and near-visible portions of the electromagnetic spectrum (roughly 0.4 to 1.0 micrometers in wavelength) from longwave radiation (infra-red radiation).

Sling psychrometer - a psychrometer in which the wet and dry bulb thermometers are mounted upon a frame and connected to a handle at one end by means of a bearing or a length of chain. It may be whirled in the air for the simultaneous measurement of wet and dry bulb temperatures.

Solar intensity - the amount of solar radiation.

Solenoid value - a value actuated by a solenoid or an electronic impulse for controlling the flow of gases or liquids in pipes.

Space heating - interior heating of a building or room.

Stagnation - the condition of a fluid or gas unstirred by a current or flow.

Thermal comfort - the zone in which a majority of the human population would not feel too hot or too cold.

Thermal lag - the ability of materials to delay the transmission of heat; can be used interchangeably with time lag.

Thermal sensation - the ability of the body to sense the temperature as being too hot or too cold.

Time lag - the time between a cause and a resultant effect, as between occurrence of heat input on an exterior surface of a wall and the time until the heat is transmitted to the interior wall surface.

Ton (of air conditioning) - the thermal refrigeration energy required to melt one ton of ice (2,000 pounds); equals 12,000 BTU.

"U" value - a coefficient which indicates the energy (BTU) which passes through a component for every degree (Fahrenheit) of temperature difference from one side to the other under steady state conditions.

Vapor barrier - a component of construction which is impervious to the flow of moisture or air.

Vapor pressure - the force exerted when moist air attempts to seek equilibrium by migrating to areas with less water vapor.

Ventilation air - outside air that is intentionally allowed to enter an interior space.

Weatherstripping - foam, metal, or rubber strips used to form a seal around windows, doors, or openings to reduce infiltration.

Wet bath temperature - the lowest temperature attainable by evaporating water into the air, without altering the energy content.

MODULE #10

UNIT I Fundamentals of Heating and Cooling Introduction

A. Energy Units

B. Temperature Differences

C. Humidity

UNIT II Heating Systems

Introduction

A. Forced Air Components

B. Sizing a Heating System

C. Fuel Costs

D. Heating System Efficiency

1. Fuel Furnaces

2. Electric Furnaces

3. Heat Pumps

4. Electric Baseboard Heaters

E. Maintenance

1. Filters

2. Fans

3. Adjusting LPG and Natural Gas Furnaces

a. Gas Valves

b. Adjusting the Air Mixture

c. Cleaning the Burners

d. Adjusting the Gas Pressure

e. Adjusting the Pilot Light

4. Electric Furnaces

a. Maintaining the Fan

b. Checking the Thermostat

F. Humidifiers

1. Operation and Maintenance

2. Fuel Savings

G. Space Heaters

H. Energy Saving Tips for Heating

UNIT III Cooling Systems

A. Air Conditioner Components

B. Types of Air Conditioners

1. Room Air Conditioners

2. Central Air Conditioning Systems

C. Sizing a Cooling System

D. Maintenance and Use

E. Dehumidify in Summer

F. Tips for Cooling Energy Savers

UNIT IV Duct Work

A. Calculation of Duct Size

B. Types of Ducts

C. Duct System Designs

D. Insulation of Ducts

MODULE #10

HEATING, VENTILATING, AND AIR CONDITIONING
CONSERVATION OPPORTUNITIES

UNIT I

OBJECTIVES: Upon completion of this unit the student will be able to:

a. Discuss energy use in the U.S. in terms of types of fuel used for various activities.

b. Identify units of measurement for energy fuel used in heating and cooling.

1. Watt
2. Kilowatt
3. British Thermal Unit (BTU)
4. Cubic foot (CFM)

c. Define terms related to heating and cooling fundamentals:

1. Heat Load
2. Heat Gain
3. Cooling Load
4. Tons of Refrigeration
5. Energy Efficiency Ratio
6. Temperature Difference
7. Summer Design Temperature
8. Winter Design Temperature
9. Inside Temperature
10. Relative Humidity
11. Humidifier
12. Dehumidifier
13. Ventilation
14. Infiltration

UNIT 1:

FUNDAMENTALS OF HEATING AND COOLING

INTRODUCTION

Non-renewable energy (coal, gas, and oil, is used in our homes. Due to diminishing supplies, curtailments, and real or fabricated shortages, energy prices are rising; in no area do we experience this more than in our heating and cooling bills. As shown in Figure 1.1, 15.7 per cent of our total U.S. energy budget is devoted to heating (space and water) and cooling (air conditioning and refrigeration). When we search for ways to simplify our lifestyles, there is no better place to start.

We can maximize efficiency by insulating homes and offices, as discussed in Module #8. Keeping our heating and cooling systems in proper working order will also cut costs. We can operate energy-wasteful appliances only when it is absolutely necessary and at non-peak load hours; (See Module #7) and everyone should practice conservation measures such as using hot water sparingly.(Module #6)

FIGURE 1.1

ENERGY USE
Per Cent of Total U.S. Energy Use in Residential Sector

Wood		nil
Coal		nil
Natural gas		7.3%
Electricity		7.5%
Oil		4.4%
	Total	19.2%

Space heating	11.0%	
Water heating	2.9%	15.7%
Air conditioning	0.7%	
Refrigeration	1.1%	
Cooking	1.1%	
Lighting	0.7%	
Other (small appliances)	1.7%	
Total	19.2%	

This module will discuss the design, installation, and proper use of space heating and cooling systems for the home and will touch on energy saving tips for the consumer. Once a basic house is designed, to include amounts of insulation, types and sizes of windows, size and shape of the house, orientation, etc. (Refer to Module #8), the homeowner must then determine the heat loss and heat gain requirement of a building so that a balance between the two can be obtained by properly adding a space heating system and a cooling system. (See Module #8). This is one of the most important considerations in discussing energy use and energy abuse in a home.

The first step in reducing energy consumption and fuel bills is to understand some of the basic principles of heating and cooling. Most energy is consumed in the home through the operation of furnaces, air conditioners, ovens, and refrigerators. By understanding how heating and cooling take place, one can gain a real insight into the factors that make these units work efficiently.

First, one must always remember that the total heating or cooling bill depends upon two factors: the efficiency of a furnace, air conditioner, or other appliances and the amount of work one is asked it to do. Efficiency is a measure of how much energy is wasted in doing a particular job; 100% efficiency means no wasted energy, while 50% means half is wasted. A fact too often ignored is the actual amount of work required to do the job. A poorly insulated house requires far more energy to heat and cool than a well insulated house. Sealing air leaks, adding more insulation, and doing other simple jobs can do far

Discuss the following terms:

Thermostat

more to reduce fuel blls than buying the most sophisticated, expensive, high-efficiency furnace or air conditioner on the market.

Most homes today have fully controlled temperatures all year around. In the winter the home is heated by a furnace; in the summer it is cooled by an air conditioner. The inside temperature is regulated by a thermostat. Although there are many different types, brands, and models of heating and cooling equipment, the basic purpose is the same--to keep the occupants comfortable, neither too hot nor too cold.

Heating and cooling a home costs money. Electricity is consumed, gas and oil are burned, and one pays for what is used. The object then is to use as little energy as possible to heat and cool the home. Using efficient equipment is one way to cut down energy consumption, and adding insulation is another. (We have already discussed adding insulation in Module #8) Efficient equipment makes it possible to use energy in the least wasteful manner, while insulation slows down the escape of heat energy in the winter and the entrance of heat in the summer.

ENERGY UNITS

Energy Units is something bought in measured amounts. Different kinds of energy come in different forms and are measured using different units. For example, one buys natural gas by the cubic foot, gasoline and fuel oil by the gallon, and coal by the ton. But energy consumption does not take place instantly--it takes time to use up the fuel.

output of the candle is actually one BTU per hour.

Home heating requirements are also figured in BTU. The heat load is the amount of heat that escapes from the structure through--walls, windows, doors, ceilings, floors, etc. If a house has a 100,000 BTU heat load (figured on the coldest expected temperature), it will require a furnace with at least 100,000 BTU capacity to heat the home.

When air-conditioning a home, the term heat gain or cooling load is used to specify the amount of het that must be removed from the home. A home having a summer heat gain of 36,000 BTU (figured on the hottest typical day) would require an air conditioner rated at 36,000 BTU. This cooling capacity is easily accomplished with a moderate--sized central air-conditioning unit, or several smaller window-mounted units totaling 36,000 BTU.

larger air conditioners are normally measured in tons of refrigeration, which has nothing to do with the air conditioner's actual weight. In this system, one ton of cooling capacity corresponds to 12,000 BTU. Thus, a 36,000 BTU air conditioner could also be rated as a 3-ton air conditioner. This unit came about in the early "icebox" days of refrigeration because it represented the amount of heat energy required to melt one ton of ice in 24 hours.

Since the BTU and the watt-hour are both units of heat energy, there is a simple conversion factor that can be used to relate them. Once watt-hour is roughly 3.4 BTU. Similarly, one kilowatt-hour is about 3,400 BTU.

Discuss the meaning of these terms:

Watt

Kilowatt

British Thermal Unit

Heat Load

Heat Gain

Cooling Load

Tons of Refrigeration

Energy Efficiency Ratio

Temperature Difference

Inside Temperature

Relative Humidity

Humidifier

Dehumidifier

Ventilation

Infiltration

Electrical energy is sometimes confusing because it is not measured in a unit or quantity that one can see. Electrical appliances are rated in watts which is an indication of the power they consume. Power and energy are not the same things. The electric meter records energy consumption in watt-hours or kilowatt-hours. (The prefix kilo means 1000, so a kilowatt is 1000 watts) In other words, energy is equal to the product of power and time. If one burns a 100-watt light bulb for one hour, one will have consumed 100 watt-hours of electrical energy. If a person burns the same bulb for two hours, it would have consumed 200 watt-hours, or 0.2 kilowatt-hours. If the electric power company charges 5 cents per kilowatt-hour, then 0.2 KWH would cost 0.2 X 5 = 1 cent.

The British thermal unit (BTU) is the basic unit used in measuring heat energy. The energy capacity of both heating and cooling equipment is measured with this unit. For example, a moderate-sized home in one of the northern states might have a furnace rated at 100,000 BTU and a central air conditioner rated at 36,000 BTU. The furnace is rated on the basis of how much heat it can deliver to the house, while the air conditioner is rated by how much heat it can remove from the house. As these figures indicate, one BTU represents a fairly small amount of heat energy. Technically speaking, a BTU is the amount of heat required to raise the temperature of one pound of water by one degree Fahreheit. However, it is easier to visualize by thinking of a BTU as being about equal to the heat delivered in one hour by the flame of one candle on a birthday cake. The one hour refers to the heat

To convert watts to BTU, simply multiply the number of watts by 3.4. Alternatively, to convert BTU to watts, divide the BTU rating by 3.4. Electrical heating equipment is sometimes sized in watts instead of BTU. This is particularly the case with baseboard heaters and space heaters.

The energy efficiency ratio (EER) is a handy way of comparing the efficiencies of various air conditioners. The EER is equal to the BTU rating divided by the input watts. Air conditioners do not produce heat directly, instead they merely transfer or pump heat energy from one place to another. In a refrigerator, for instance, the motor pumps Freon gas through coils located on the inside and outside of the refrigerator. One coil absorbs and removes heat energy from the inside, making it cold, while the second coil dissipates the heat into the outside air circulating over its fins. The advantage here is that it takes less energy to pump heat around than it does to generate it, as in a heater. This is proven by the fact that typical conditioners have an EER between 5 and 10 that a typical air conditioner is capable of removing about 25 times as much heat energy from the home as the unit itself consumes in electrical energy.

The EER for an air conditioner is determined under prescribed test conditions of temperature and humidity, and this is done so that one can easily compare the performance of all air conditioners. But it must be pointed out that temperatures will vary in actual operation and so will the efficiency with which an air conditioner can pump heat out of the house. The official EER rating reflects a typical summeroperating condition: however, one can expect that an air conditioner will use more electrical energy on really hot days and less on cool days.

TEMPERATURE DIFFERENCES

Temperatures are generally measured in degrees Fahrenheit in the U.S. although the metric Celcius (or centigrade) scale-used almost everywhere else in the world-is catching up with us. On the Celcius scale, 0°C (212°F) represents the boiling point of water. In terms of room temperature, 20°C (68°F) is just a bit on the chilly side, while 25°C (77°F) is just a bit on the warm side. Throughout this book temperatures will be given in Fahrenheit unless otherwise noted.

The temperature difference is the difference between the inside and outside temperatures of a building. As the temperature difference increases, the heat load or cooling load also increases. Consequently, it will take more fuel to heat a house when the difference between the inside and outside temperatures is 70 degrees than when the temperature difference is only 30 degrees.

Design temperatures vary according to location in the nation. The winter design temperature tells how cold it will get in an area. It will determine the heat load of the home and, therefore, the size of the required heating unit. For example, the winter design temperature in Milwaukee, Wisconsin is -17°F. The temperature difference for a home in Milwaukee with its thermostat set at 63°F would then be 85 degrees. Similarly, the winter design temperature in Jacksonville, Florida is 33°F, so for the same thermostat setting, the Milwaukee home would require a much larger heating unit than an identical home in Jacksonville.

Figure 1.2 - gives a sample of design temperature for heating.

DESIGN TEMPERATURES FOR HEATING

FIGURE 1.2

The following table lists the outdoor winter temperatures in common use in these areas. These are recommended for use as the basis for preparing heating estimates.

State & City	Design Temp. °F
ALABAMA	
Anniston	10
Birmingham	10
Gadsden	10
Mobile	20
Montgomery	20
Tuscaloosa	10
ALASKA	
Anchorage	-26
Barrow	-48
Bethel	-43
Cordova	-13
Fairbanks	-57
Juneau	-5
Kotzebue	6
Nuiqsut	6
Kotzebue	-44
Nome	-36
Seward	-4
Sitka	7
ARIZONA	
Bisbee	30
Flagstaff	-5
Globe	26
Nogales	30
Phoenix	35
Tucson	30
Winslow	-5
Yuma	40
ARKANSAS	
Bentonville	0
Fort Smith	5
Hot Springs	10
Little Rock	10
Pine Bluff	10
Texarkana	10
CALIFORNIA	
Bakersfield	30
El Centro	35
Eureka	30
Fresno	30
Long Beach	35
Los Angeles	40
Montague	15
Needles	25
Oakland	30
Pasadena	40
Red Bluff	15
Sacramento	30
San Bernardino	30
San Diego	45
San Francisco	35
San Jose	40
COLORADO	
Boulder	-15
Colorado Springs	-10
Denver	-10
Durango	-5
Fort Collins	-15
Grand Junction	-5
Leadville	-15
Pueblo	-15
CONNECTICUT	
Bridgeport	0
Hartford	0
New Haven	0
New London	5
Norwalk	0
Torrington	0
Waterbury	0
DELAWARE	
Dover	10
Milford	10
Wilmington	5
DIST. OF COLUMBIA	
Washington	15
FLORIDA	
Apalachicola	25
Fort Myers	40
Gainesville	30
Jacksonville	30
Key West	55
Miami	45
Orlando	35
Pensacola	25
Tallahassee	25
Tampa	35
GEORGIA	
Athens	10
Atlanta	10
Augusta	20
Brunswick	25
Columbus	20
Macon	20
Rome	10
Savannah	25
Way Cross	25
IDAHO	
Boise	-10
Idaho Falls	-15
Lewiston	-10
Pocatello	-15
Twin Falls	-15
ILLINOIS	
Aurora	-10
Bloomington	-10
Cairo	0
Champaign	-10
Chicago	-10
Danville	-10
Decatur	-10
Elgin	-15
Joliet	-10
Moline	-10
Peoria	-15
Rockford	-15
Rock Island	-10
Springfield	-10
Urbana	-10
INDIANA	
Elkhart	-10
Evansville	-5
Fort Wayne	-5
Indianapolis	-10
Lafayette	-10
South Bend	-10
Terre Haute	-5
IOWA	
Burlington	-10
Cedar Rapids	-15
Charles City	-20
Clinton	-15
Council Bluffs	-15
Davenport	-10
Des Moines	-15
Dubuque	-15
Fort Dodge	-15
Keokuk	-15
Marshalltown	-15
Sioux City	-15
Waterloo	-15
KANSAS	
Atchison	-10
Concordia	-10
Dodge City	-10
Erie	-5
Leavenworth	-10
Salina	-10
Topeka	-10
Wichita	-5
KENTUCKY	
Bowling Green	0
Frankfort	0
Hopkinsville	0
Lexington	0
Louisville	0
Owensboro	0
Shelbyville	0
LOUISIANA	
Alexandria	20
Baton Rouge	20
New Orleans	25
Shreveport	15
MAINE	
Augusta	-15
Bangor	-20
Bar Harbor	-10
Belfast	-10
Eastport	-20
Lewiston	-10
Millinocket	-15
Orono	-20
Portland	-10
Presque Isle	-20
Rumford	-15
MARYLAND	
Annapolis	10
Baltimore	15
Cambridge	10
Cumberland	0
Frederick	5
Frostburg	-5
Salisbury	10
MASSACHUSETTS	
Amherst	-5
Boston	0
Fall River	0
Fitchburg	-5
Framingham	-5
Lawrence	-5
Lowell	-5
Nantucket	0
New Bedford	0
Pittsfield	-10
Plymouth	0
Springfield	-5
Worcester	-5
MICHIGAN	
Alpena	-10
Ann Arbor	-5
Big Rapids	-5
Cadillac	-10
Calumet	-20
Detroit	-5
Escanaba	-20
Flint	-10
Grand Haven	-5
Grand Rapids	-5
Houghton	-20
Kalamazoo	-5
Lansing	-10
Ludington	-5
Marquette	-15
Muskegon	-5
Port Huron	-10
Saginaw	-10
Sault Ste. Marie	-20
MINNESOTA	
Alexandria	-25
Duluth	-25
Minneapolis	-25
Moorhead	-30
St. Cloud	-25
St. Paul	-25
MISSISSIPPI	
Biloxi	25
Columbus	10
Corinth	5
Hattiesburg	20
Jackson	15
Meridian	15
Natchez	15
Vicksburg	15
MISSOURI	
Columbia	-10
Hannibal	-10
Kansas City	-10
Kirksville	-10
St. Joseph	-10
St. Louis	-5
Springfield	-5
MONTANA	
Anaconda	-30
Billings	-30
Butte	-30
Great Falls	-40
Havre	-40
Helena	-40
Kalispell	-40
Miles City	-35
Missoula	-30
NEBRASKA	
Grand Island	-15
Hastings	-15
Lincoln	-15
Norfolk	-15
North Platte	-15
Omaha	-15
Valentine	-20
York	-15
NEVADA	
Elko	-10
Las Vegas	10
Reno	5
Tonopah	5
Winnemucca	-10
NEW HAMPSHIRE	
Berlin	-15
Claremont	-15
Concord	-10
Franklin	-15
Hanover	-15
Keene	-10
Manchester	-10
Nashua	-10
Portsmouth	-5
NEW JERSEY	
Asbury Park	5
Atlantic City	10
Bayonne	0
Belvidere	0
Bloomfield	0
Bridgeton	5
Camden	5
East Orange	0
Elizabeth	0
Jersey City	0
Newark	0
New Brunswick	5
Paterson	0
Phillipsburg	0
Trenton	0
NEW MEXICO	
Albuquerque	10
El Morro	0
Raton	-5
Roswell	5
Santa Fe	5
Tucumcari	5
NEW YORK	
Albany	-10
Auburn	-10
Binghamton	-5
Buffalo	-5
Canton	-20
Cortland	-10
Elmira	-5
Glens Falls	-15
Ithaca	-5
Jamestown	-5
Lake Placid	-15
New York	5
Niagara Falls	-5
Ogdensburg	-20
Oneonta	-10
Oswego	-5
Port Jervis	0
Rochester	-5
Schenectady	-10
Syracuse	-10
Watertown	-15
NORTH CAROLINA	
Asheville	5
Charlotte	15
Greensboro	10
Hatteras	20
New Bern	20
Raleigh	15
Salisbury	10
Wilmington	20
Winston-Salem	10
NORTH DAKOTA	
Bismarck	-30
Devils Lake	-30
Dickinson	-30
Fargo	-30
Grand Forks	-30
Jamestown	-30
Minot	-35
Pembina	-35
Williston	-35
OHIO	
Akron	-5
Cincinnati	-5
Cleveland	-5
Columbus	-5
Dayton	-5
Lima	-5
Marion	-5
Sandusky	-5
Toledo	-5
Warren	-5
Youngstown	-5
OKLAHOMA	
Ardmore	5
Bartlesville	-5
Guthrie	0
Muskogee	0
Oklahoma City	0
Tulsa	0
Waynoka	-5
OREGON	
Arlington	5
Baker	-15
Eugene	15
Medford	20
Pendleton	-10
Portland	10
Roseburg	20
Salem	15
Wamic	0
PENNSYLVANIA	
Altoona	-5
Bethlehem	0
Coatesville	5
Erie	-5
Harrisburg	5
New Castle	-5
Oil City	-5
Philadelphia	5
Pittsburgh	-5
Reading	5
Scranton	0
Warren	-5
Williamsport	-5
York	5
RHODE ISLAND	
Block Island	5
Bristol	0
Kingston	0
Pawtucket	0
Providence	0
SOUTH CAROLINA	
Charleston	20
Columbia	20
Florence	20
Greenville	10
Spartanburg	10
SOUTH DAKOTA	
Aberdeen	-25
Huron	-20
Pierre	-20
Rapid City	-20
Sioux Falls	-20
Watertown	-25
TENNESSEE	
Chattanooga	10
Jackson	5
Johnson City	0
Knoxville	5
Memphis	5
Nashville	5
TEXAS	
Abilene	5
Amarillo	0
Austin	15
Brownsville	30
Corpus Christi	25
Dallas	10
Del Rio	20
El Paso	20
Fort Worth	10
Galveston	25
Houston	20
Palestine	10
Port Arthur	20
San Antonio	20
Waco	10
UTAH	
Logan	-10
Milford	-5
Ogden	-5
Salt Lake City	0
VERMONT	
Bennington	-10
Burlington	-15
Montpelier	-20
Newport	-20
Northfield	-20
Rutland	-15
VIRGINIA	
Cape Henry	15
Charlottesville	10
Danville	10
Lynchburg	10
Norfolk	15
Petersburg	10
Richmond	10
Roanoke	5
Wytheville	5
WASHINGTON	
Aberdeen	20
Bellingham	10
Everett	15
North Head	20
Olympia	15
Seattle	15
Spokane	-15
Tacoma	15
Tatoosh Island	20
Walla Walla	-10
Wenatchee	-10
Yakima	-5
WEST VIRGINIA	
Bluefield	0
Charleston	0
Elkins	-5
Fairmont	0
Huntington	0
Martinsburg	0
Parkersburg	0
Wheeling	-5
WISCONSIN	
Ashland	-25
Beloit	-15
Eau Claire	-20
Green Bay	-20
La Crosse	-20
Madison	-20
Milwaukee	-15
Oshkosh	-20
Sheboygan	-20
WYOMING	
Casper	-25
Cheyenne	-20
Lander	-30
Sheridan	-30
Yellowstone Park	-35

Summer design temperatures also vary according to location. The summer design temperature tells how hot it is expected to get in the summer. In Milwaukee the summer design temperature is 95°F, while in Jacksonville it is 104°F. The air conditioners used in these areas must be sized according to the summer design temperatures.

Figure 1.3 shows the design temperature for cooling.

DESIGN TEMPERATURES FOR AIR CONDITIONING

FIGURE 1.3

(OUTSIDE DRY- AND WET-BULB TEMPERATURES)

State & City	Summer DB	Summer WB
[illegible]		
[illegible]	95	79
[illegible]	95	78
[illegible]	95	78
[illegible]	90	80
[illegible]	95	79
[illegible]	95	78
ARIZONA		
[illegible]	100	72
[illegible]	85	61
[illegible]	105	76
[illegible]	105	72
[illegible]	105	74
[illegible]	100	72
[illegible]	95	65
[illegible]	110	78
ARKANSAS		
[illegible]	95	78
[illegible]	95	78
[illegible]	95	78
[illegible]	95	78
[illegible]	95	78
Texarkana	100	78
CALIFORNIA		
[illegible]	105	78
[illegible]	110	78
[illegible]	90	65
[illegible]	105	78
Long Beach	95	78
Los Angeles	90	78
[illegible]	95	78
[illegible]	115	—
[illegible]	80	65
[illegible]	95	78
[illegible]	100	78
Sacramento	100	72
San Bernardino	105	72
San Diego	80	66
San Francisco	80	65
San Jose	90	70
COLORADO		
Boulder	95	61
Colorado Springs	95	65
Denver	95	64
[illegible]	95	65
[illegible]	95	65
[illegible]	95	65
Pueblo	95	65
CONNECTICUT		
[illegible]	85	75
[illegible]	93	75
New Haven	85	75
New London	85	75
Norwalk	85	75
[illegible]	90	75
[illegible]	90	75
DELAWARE		
Dover	90	78
Milford	95	78
[illegible]	90	78
DIST. OF COLUMBIA		
Washington	90	78
FLORIDA		
[illegible]	95	80
Fort Myers	95	78
[illegible]	95	78
Jacksonville	95	78
[illegible] West	100	78
[illegible]	93	79
[illegible]	99	78
[illegible]	95	78
[illegible]	95	78
Tampa	95	78
GEORGIA		
[illegible]	95	76
[illegible]	95	76
[illegible]	100	76
[illegible]	95	78
[illegible]	100	76
[illegible]	95	78
[illegible]	95	78
[illegible]	95	78
IDAHO		
[illegible]	95	67
[illegible] Falls	90	67
[illegible]	95	67
[illegible]	93	65
[illegible] Falls	95	65

State & City	Summer DB	Summer WB
ILLINOIS		
Aurora	95	75
Bloomington	95	76
Canton	100	76
Champaign	95	77
Chicago	95	75
Danville	95	77
Decatur	95	77
Elgin	95	78
Joliet	95	76
Moline	95	76
Peoria	95	76
Rockford	95	76
Rock Island	95	76
Springfield	95	77
Urbana	95	77
INDIANA		
Elkhart	95	75
Evansville	95	78
Fort Wayne	95	75
Indianapolis	95	76
Lafayette	95	76
South Bend	95	75
Terre Haute	95	78
IOWA		
Burlington	95	78
Cedar Rapids	95	78
Charles City	95	75
Clinton	95	78
Council Bluffs	100	78
Davenport	95	78
Des Moines	95	78
Dubuque	95	78
Fort Dodge	95	78
Keokuk	95	78
Marshalltown	95	78
Sioux City	95	78
Waterloo	95	78
KANSAS		
Atchison	100	76
Concordia	95	78
Dodge City	95	78
Erie	100	75
Leavenworth	100	76
Salina	100	76
Topeka	100	78
Wichita	100	75
KENTUCKY		
Bowling Green	95	78
Frankfort	95	76
Hopkinsville	95	76
Lexington	95	78
Louisville	95	78
Owensboro	95	78
Shelbyville	95	78
LOUISIANA		
Alexandria	95	78
Baton Rouge	95	80
New Orleans	95	80
Shreveport	95	78
MAINE		
Augusta	85	73
Bangor	85	73
Bar Harbor	85	73
Belfast	85	73
Eastport	85	70
Lewiston	85	73
Millinocket	85	73
Orono	85	70
Portland	85	73
Presque Isle	85	73
Rumford	85	73
MARYLAND		
Annapolis	90	78
Baltimore	90	78
Cambridge	90	78
Cumberland	90	75
Frederick	90	78
Frostburg	90	75
Salisbury	90	78
MASSACHUSETTS		
Ayer	90	75
Boston	85	74
Fall River	85	75
Fitchburg	90	75
Framingham	90	75
Lawrence	85	74
Lowell	85	74
Nantucket	85	75
New Bedford	85	75
Pittsfield	90	75
Springfield	90	75
Worcester	90	75

State & City	Summer DB	Summer WB
MICHIGAN		
Alpena	90	75
Ann Arbor	90	75
Big Rapids	90	75
Cadillac	90	75
Calumet	85	73
Detroit	90	75
Escanaba	85	74
Flint	90	75
Grand Haven	90	75
Grand Rapids	90	74
Houghton	80	73
Kalamazoo	90	75
Lansing	90	75
Ludington	90	75
Marquette	80	73
Muskegon	90	74
Port Huron	90	75
Saginaw	90	75
Sault Ste. Marie	80	71
MINNESOTA		
Alexandria	85	74
Duluth	80	71
Minneapolis	90	76
Moorhead	95	75
St. Cloud	90	75
St. Paul	90	75
MISSISSIPPI		
Biloxi	90	80
Columbus	95	78
Corinth	95	78
Hattiesburg	95	80
Jackson	95	78
Meridian	95	79
Natchez	95	78
Vicksburg	95	78
MISSOURI		
Columbia	100	78
Hannibal	95	77
Kansas City	100	78
Kirksville	95	78
St. Joseph	100	78
St. Louis	95	78
Springfield	100	77
MONTANA		
Anaconda	85	59
Billings	90	66
Butte	85	59
Great Falls	90	63
Havre	95	70
Helena	90	63
Kalispell	90	63
Miles City	95	69
Missoula	90	63
NEBRASKA		
Grand Island	100	75
Hastings	100	75
Lincoln	95	78
Norfolk	95	78
North Platte	100	73
Omaha	100	78
Valentine	95	78
York	95	78
NEVADA		
Elko	95	63
Las Vegas	110	71
Reno	95	65
Tonopah	90	63
Winnemucca	95	65
NEW HAMPSHIRE		
Berlin	85	73
Claremont	85	73
Concord	85	73
Franklin	85	73
Hanover	85	73
Keene	85	73
Manchester	85	74
Nashua	85	74
Portsmouth	85	74
NEW JERSEY		
Asbury Park	90	78
Atlantic City	90	78
Bayonne	90	75
Belvedere	90	75
Bloomfield	90	75
Bridgeton	90	78
Camden	90	78
East Orange	90	75
Elizabeth	90	75
Jersey City	90	75
Newark	90	76
New Brunswick	90	75
Paterson	90	76
Phillipsburg	90	75
Trenton	90	78

State & City	Summer DB	Summer WB
NEW MEXICO		
Albuquerque	95	65
El Morro	85	65
Raton	95	65
Roswell	100	71
Santa Fe	90	65
Tucumcari	95	70
NEW YORK		
Albany	90	74
Auburn	90	74
Binghamton	90	72
Buffalo	85	73
Canton	85	73
Cortland	90	74
Elmira	90	73
Glens Falls	90	73
Ithaca	90	73
Jamestown	90	74
Lake Placid	90	72
New York	90	76
Niagara Falls	85	73
Ogdensburg	85	73
Oneonta	90	73
Oswego	90	74
Port Jervis	90	75
Rochester	90	74
Schenectady	90	74
Syracuse	90	74
Watertown	85	73
NORTH CAROLINA		
Asheville	90	75
Charlotte	95	78
Greensboro	90	76
Hatteras	90	80
New Bern	95	78
Raleigh	95	78
Salisbury	90	78
Wilmington	90	81
Winston-Salem	90	76
NORTH DAKOTA		
Bismarck	95	73
Devils Lake	90	70
Dickinson	95	70
Fargo	95	75
Grand Forks	90	72
Jamestown	95	73
Minot	90	71
Pembina	90	73
Williston	90	73
OHIO		
Akron	90	75
Cincinnati	95	78
Cleveland	90	75
Columbus	90	76
Dayton	90	76
Lima	90	75
Marion	90	75
Sandusky	90	75
Toledo	90	75
Warren	90	75
Youngstown	90	75
OKLAHOMA		
Ardmore	100	78
Bartlesville	100	77
Guthrie	100	77
Muskogee	95	79
Oklahoma City	100	77
Tulsa	100	77
Waynoka	105	75
OREGON		
Arlington	95	68
Baker	90	66
Eugene	90	68
Medford	95	68
Pendleton	90	66
Portland	85	68
Roseburg	90	66
Salem	90	68
Wamic	90	66
PENNSYLVANIA		
Altoona	90	75
Bethlehem	90	75
Coatesville	90	75
Erie	85	74
Harrisburg	90	75
New Castle	90	75
Oil City	90	75
Philadelphia	90	78
Pittsburgh	90	75
Reading	90	75
Scranton	90	75
Warren	90	75
Williamsport	90	74
York	90	75
RHODE ISLAND		
Block Island	85	75
Bristol	90	75
Kingston	85	75
Pawtucket	90	75
Providence	90	75

State & City	Summer DB	Summer WB
SOUTH CAROLINA		
Charleston	90	80
Columbia	95	78
Florence	95	79
Greenville	95	75
Spartanburg	95	78
SOUTH DAKOTA		
Aberdeen	95	75
Huron	100	75
Pierre	95	73
Rapid City	95	70
Sioux Falls	95	75
Watertown	95	73
TENNESSEE		
Chattanooga	95	78
Jackson	95	78
Johnson City	95	78
Knoxville	95	75
Memphis	95	78
Nashville	95	78
TEXAS		
Abilene	95	74
Amarillo	95	72
Austin	100	78
Brownsville	95	80
Corpus Christi	95	80
Dallas	100	78
Del Rio	100	78
El Paso	100	69
Fort Worth	100	78
Galveston	95	80
Houston	95	80
Palestine	100	78
Port Arthur	95	80
San Antonio	100	78
Waco	100	78
UTAH		
Logan	95	65
Milford	95	66
Ogden	90	65
Salt Lake City	95	65
VERMONT		
Bennington	90	73
Burlington	90	73
Montpelier	90	73
Newport	85	73
Northfield	90	73
Rutland	90	73
VIRGINIA		
Cape Henry	90	78
Charlottesville	90	78
Danville	90	78
Lynchburg	90	78
Norfolk	90	78
Petersburg	90	78
Richmond	90	78
Roanoke	90	76
Wytheville	90	78
WASHINGTON		
Aberdeen	85	64
Bellingham	80	65
Everett	80	65
North Head	80	65
Olympia	80	64
Seattle	80	65
Spokane	88	65
Tacoma	80	64
Tatoosh Island	80	65
Walla Walla	95	65
Wenatchee	90	65
Yakima	90	67
WEST VIRGINIA		
Bluefield	95	75
Charleston	90	75
Elkins	90	73
Fairmont	90	75
Huntington	90	76
Martinsburg	90	75
Parkersburg	90	75
Wheeling	90	75
WISCONSIN		
Ashland	80	71
Beloit	95	75
Eau Claire	90	75
Green Bay	90	75
La Crosse	95	75
Madison	90	75
Milwaukee	90	75
Oshkosh	90	75
Sheboygan	90	75
WYOMING		
Casper	90	62
Cheyenne	90	62
Lander	90	62
Sheridan	90	65
Yellowstone Park	85	62

The inside temperature in a home is regulated by using heating and cooling equipment. However, the inside temperature also affects the temperature difference between the inside and outside of the house. Thus the setting of the thermostat changes the heating and cooling load of the home. Lowering the thermostat in the winter lowers the heat load of the home, meaning that less energy is consumed by the furnace in maintaining the home at the desired temperature. Raising the inside temperature of the home during the summer means that the cooling load is reduced and the air conditioner doesn't have to work as hard.

A point to remember is that the heating and cooling loads for a home will not be the same because different temperatures are involved. A house with a heat load of 80,000 BTU will not have a cooling load of 80,000 BTU except possibly in some southern states. In a typical northern state, the house might have an 80,000 BTU heat load and a 36,000 BTU cooling load. The difference in heating and cooling loads results because the loads are figured using different design temperatures and inside temperatures, and also because they include solar heating effects due to sunlight. The heating and cooling loads in areas can be found for almost any structure by using charts and tables designed for that very purpose.

The heating and cooling loads, and hence fuel bills, are also affected by what is inside the building. Appliances such as stoves, toasters, irons, ovens, washers, and dryers produce heat. Lamps, in addition to giving light, also contribute heat. People, whether sitting or actively moving about, also generate varying amounts of body heat. In the winter this extra heat is welcomed because it lowers the heating load, but in the summer this extra heat places an added burden on the air-conditioning system that must remove it.

People, whether sitting or actively moving about, also generate varying amounts of body heat. In the winter this extra heat is welcomed because it lowers the heating load, but in the summer this extra heat places an added burden on the air conditioning system that must remove it.

HUMIDITY

Humidity refers to the amount of water vapor or moisture in the air. Warm air can hold more water vapor than cool air, so warm air speeds up evaporation. Relative humidity is a way of expressing the percentage of moisture contained in the air at a specific temperature. For example, 50% relative humidity means that the air is holding only half as much moisture as it is capable of holding at that temperature. Raising or lowering the temperature will change the relative humidity. In a sealed house, as the temperature rises, the relative humidity decreases; and as the temperature falls, the relative humidity increases. If the temperature falls enough, as when the air circulates over a cold beverage glass, the relative humidity reaches 100% and water begins to condense out of the air, forming drops of water on the glass.

High humidity and condensation can be very bad in a home, making the air feel clammy, rotting window moldings, and rusting tools and equipment. On the other hand, too little humidity makes the air feel dry, increases static electricity, and causes wood to dry and shrink. Consequently, both humidifiers and dehumidifiers are often used in homes to control the relative humidity to within comfortable limits.

Since air conditioners also dehumidify the air by condensing and removing water vapor, it is desirable to select a unit with the right cooling capacity so that it will properly control both the humidity and temperature of the home. (Refer to Module #9 for a discussion of relative humidity, wet bulb temperatures, dry bulb temperatures, and human comfort zones.)

The motion of the air in a home plays many important roles. Too much air motion can make a home feel drafty, while too little air motion prevents a uniform heating and cooling of the air. Air coming into the house from outside, and the subsequent loss of air from inside, is also a major source of heat loss and heat gain. Sometimes this outside air is desirable, sometimes it is not. Fresh air can supply oxygen and remove stale odors, but most homes ordinarily have enough air entering through the opening and closing of doors that no additional air is needed. In general, the air movement into and out of a home can occur in two different ways: ventilation and infiltration.

Ventilation occurs when air is intentionally brought into the home and made to mix with the air in the building. Ventilation air can be brought into the home with a separate fan, or it can be introduced using a special vent connected in the duct system. In either case, it is necessary to control the amount of outside air brought in as well as its temperature.

Many buildings are required by law or local building codes to have a certain amount of outside ventilation air, especially,

nursing homes, hospitals, factories, and office buildings. The purpose of this ventilation air is to mix fresh air with the circulating air in order to reduce the amount of odors, bacteria, and noxious gases. The ventilation air also insures that an acceptable level of oxygen is present in the air.

The average home, though, does not need to have outside air brought into it. The attic and crawl space, however, do need ventilation. The attic space usually needs ventilation all year round to remove heat buildup in the summer and moisture in the winter. The crawl space needs venting in the summer to remove moisture that would rot beams and produce musty odors. Such ventilation is not usually desirable in the winter because it increases the heat load of the home and results in cold floors.

Ventilation in the furnace room is sometimes required by insurance and loan companies. This requirement is intended to prevent the furnace from burning up all the oxygen in the house. The furnace room is thus equipped with an outside vent to provide fresh air to the furnace burners, and the combustion gases are then exhausted safely up the chimney. In many European countries, the vent is opened and closed automatically to increase furnace efficiency, but at present this scheme is not approved in the U.S.

Infiltration air enters the home through cracks around windows and through tiny openings in the walls, ceilings, and floors. Hearing whistling noises around doors and windows while the wind is blowing hard is listening to infiltration air. The same is

true when window shades and blinds move as the wind blows outside. This infiltration air is not intentional--a perfectly sealed home would not have any. Since infiltration air must be heated and cooled, it contributes to the heating and cooling load of the home.

Heat energy is moved or transferred from one place to another by three major methods: convection, conduction, and radiation. For a thorough discussion of these principles refer to Module #8.

SUMMARY

By putting these terms into practice the homeowner becomes aware of how his or her home is conditioned year around. It takes the harmonious balance of factors in home conditioning produces the most efficiency for the energy used and expends no more work load than is needed.

UNIT 11

HEATING SYSTEMS

OBJECTIVES: Upon the completion of this unit the student will be able to:

a. Identify the components of a forced air heating system.

b. Calculate heat loss in a home.

c. Size a heating system for a particular home heating need.

d. Explain the difference in fuel costs among energy fuels available for heating use.

e. Recognize and implement measures to improve energy efficiency in heating systems.

f. Discuss differences in efficiency among gas, oil, electric, and heat pump central systems, and baseboard and space heaters.

g. Discuss maintenance measures for heating systems.

h. Discuss the role of humidifiers in heating a home.

LECTURE

LABORATORY

INTRODUCTION:

Unless a heating system is operating at maximum efficiency, money is lost. Any time a furnace is out of adjustment or the air circulation is restricted, the heating efficiency is reduced and the operating cost is increased. Once it is understood how a heating system works and how to size a unit for a particular need, it will be easy to correct and even anticipate common problems that affect heating system efficiency.

A. FORCED AIR COMPONENTS

A central heating system consists of a furnace which serves as the source of heat, a fan to distribute the heated air, and ductwork to provide a path by which the air travels. Figure 2.1 illustrates how a forced air system operates in prinicple.

All forced air systems operate similarly...and automatically. When room temperature drops below a pre-determined minimum setting of the thermostat (A) the burner (B) starts and heats the air around the heat exchanger (C) in the furnace. When the temperature of the air in the furnace reaches the "fan on" setting of the fan control, the furnace blower (D) starts. The blower pulls the cool air from the rooms through the grilles (E) and return-air ducts (F) to the furnace. Here, the air passes through the filters (G) and circulates around the heat exchanger where it warms and picks up moisture from the humidifier (H). The cleaned, moistened and warmed air is then delivered to the registers (I) in each room through the warm-air ductwork (J). When the thermostat is satisfied, the burner automatically shuts off. The fan control should be set so that the blower runs almost continuously during cold weather. Cost of continuous blower operation is little more than for intermittent operation, and gives more comfortable, uniform heating with little chance of air stratification. A little control automatically cuts out burner if furnace overheats.

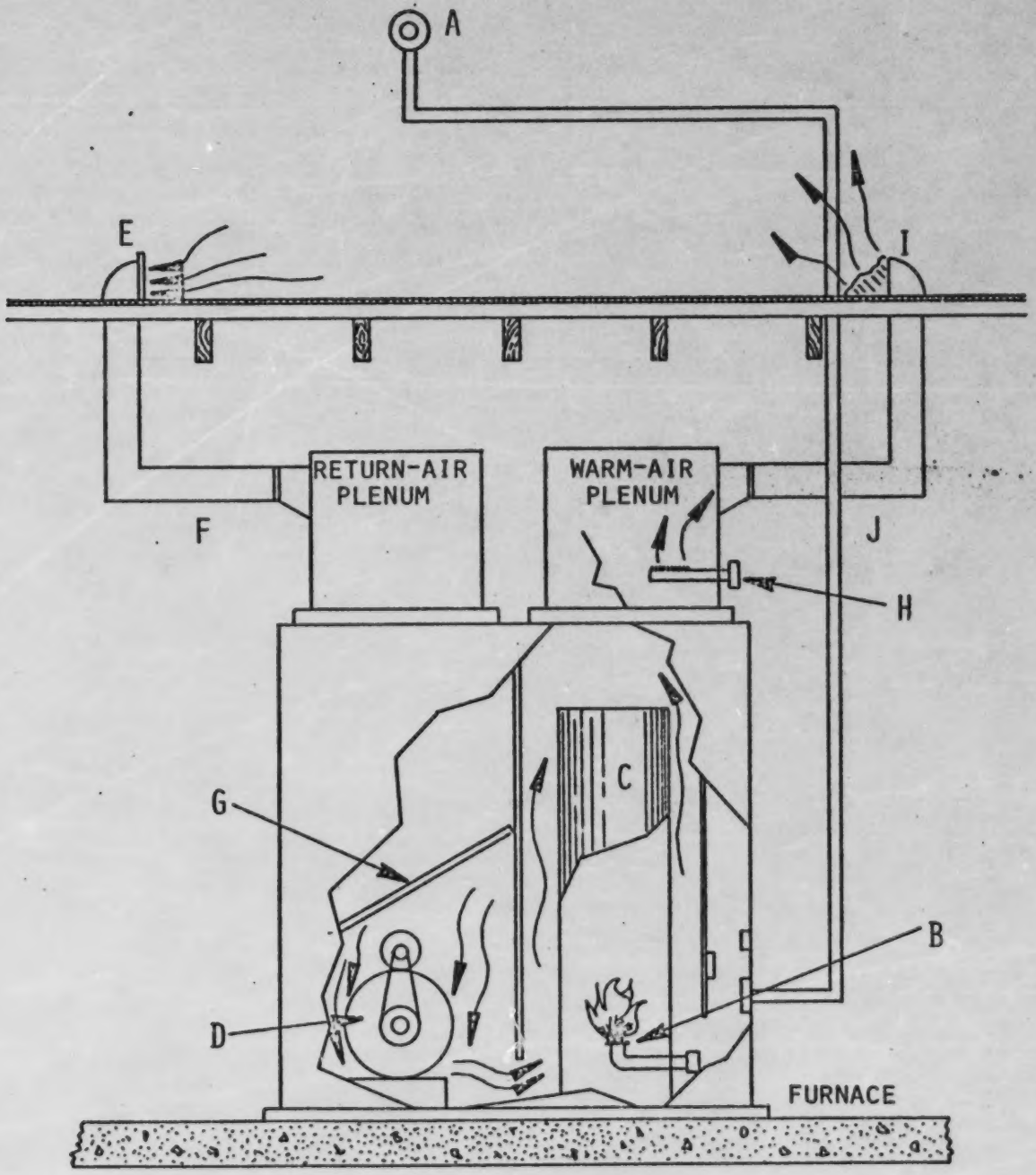
B. SIZING A HEATING SYSTEM

Once a house is designed to include insulation, types and sizes of windows, size and shape of house, orientation, the homeowner must determine the heat loss and heat gain requirements of the

An interesting activity that the students can do is to look at the effects on efficiency of changing flow rates. This can be done by partially blocking a return air duct or partially blocking or shutting the vents on a heat duct. In this case the student should have the system clean and open and do a temperature vs. time measurement on the heating of a room with the vents open and partially closed or blocked completely. When a student has part of the return duct closed, a timing should be done on how long it takes the furnace system to cycle on and off and how often it comes back on. These experiments will show how much less the efficiency and cycle time is for a furnace which has lower reduced rates of flow or which is partly blocked. In addition, filters are very important to the intake of the furnace. Dust in a fine layer is a very good insulating material. If one lets dust build up inside the pipes he/she is essentially blocking the inside of the pipes and the heat exchanger. Dust in the outer pipes may be slightly insulative but it usually is deposited in the furnace first and will reduce the plenum's efficiency or heat transfer. Also, the fine dust increases the amount of cleaning, the amount of traffic, and the amount of dirt that is in the air.

FIGURE 2.1

HEATING SYSTEM



home. This is done quite easily using the methods of calculating outlined in Module #8. For this module, however, a simplified method of estimating heating requirements will be discussed.

The most important point to be stressed in sizing and designing a heating system for a particular home is to install equipment that is no longer than required. This concept is relatively new and has gained impetus since the oil embargo of 1973 and the increasing fuel costs. It is not uncommon for buildings built prior to 1974 to have heating systems and circulation fans designed three times larger than the heating requirements. In addition to more energy consumption, oversized equipment results in short periods of operation, poor comfort conditions, and lower seasonal efficiency.

Ideally, output capacity of heating equipment should not be less than the calculated heating load. And, it should not exceed the calculated heat load by more than 15 percent. Cooling equipment output capacity should be no less than five percent below the calculated cooling load nor more than 12 percent in excess of the calculated cooling load.

Many times, however, it is not possible to obtain equipment within these limitations. If this is the case then the homeowner should consider the possibility of reducing the heat loss and heat gain of the structure to the point where properly sized equipment can be obtained. As discussed in Module #8 there are many ways to do this, such as: installing storm windows, increasing the amount of insulation, reducing the heating load by adding earth berms, etc.

Passive enhancement for heating and cooling is very important. This now only involves the opening and closing of shades in the form of moveable insulation, air flow rates from infiltration, and other passive elements that we have talked about before including insulation, but there are passive enhancement elements that can be considered within the furnace itself. These include heat exchangers to recover some of the heat that goes up the flue and more importantly for the heating cycle is to provide some sort of external source for the combustion air in the furnace. When this external source is provided, the pressure difference or the drop in pressure caused by the thermal chimney effect will cut the infiltration rate. Then a person can control the infiltration rate depending upon the number of people in the house and the current lifestyle activities.

Final selection of heating equipment depends upon the type of system selected, the lection of the system in the structure and upon the type of equipment itself. This will be discussed in greater detail in Unit IV of this Module.

Sizing a heating system means selecting a furnace and piping large enough to replace the natural loss of heat from the home. To do this properly means knowing some details about the house and local weather conditions.

Each house must be surveyed individually, because its size construction is different from any other house. Houses lose heat through exposed ceilings and floors, outer walls, windows and doors. Heat is lost through each of these areas at a different rate because of sizes, types of materials and use of insulation or storm sash.

All factors are reduced to a common measurement of heat--the BTU (British Thermal Unit). This makes it easy to match a proper size furnace or boiler (outputs expressed in BTUs) with the heat loss of any house (also expressed in BTUs).

Each geographical location has a design temperature for heating. This is not the lowest temperature recorded, but the lowest temperature reached during 97-1/2% of the time--the only practical approach in designing heating systems. Figure 2.2 gives the design temperature for heating in selected Texas cities.

All the information needed for sizing a furnace or boiler can be entered on the work sheet at Figure 2.3. Much of this information is found just by looking at the house from the outside. This includes: type of house and construction; number of windows and doors; use of storm sash.

Measure the distance around the house (perimeter). This can be paced off, for an approximation, or measured more accurately with a 50 ft. steel tape. Inside, check the ceiling height with a wood folding rule or yardstick. If you don't already know about wall and ceiling insulation, you can usually check this from the attic with a flashlight.

FIGURE 2.2

DESIGN TEMPERATURES FOR HEATING

The following table lists theoutdoor winter temperatures in common use in these areas. These are recommended for use as the basis for preparing heating estimates.

State & City	Design Temp°F
TEXAS	5°
Abilene	0°
Amarillo	15°
Brownsville	30°
Corpus Christi	25°
Dallas	10°
Del Rio	20°
El Paso	20°
Fort Worth	10°
Galveston	25°
Houston	20°
Palestine	10°
Port Arthur	20°
San Antonio	20°
Waco	10°

Figures 2.4 and 2.5 illustrate how to use the worksheet for estimating heating requirements for a sample house. Study the example before preparing your worksheet.

FIGURE 2.3

HEATING ESTIMATE WORK SHEET

TYPE OF HOUSE _____ STORY

ATTIC INSULATION ☐YES ☐NO
WALL INSULATION ☐YES ☐NO
STORM SASH ☐YES ☐NO

DESIGN TEMPERATURE
OUTSIDE _____ °F
INSIDE _____ °F
DIFFERENCE _____ °F

TYPE OF EXPOSURE		GROSS AREA IN SQUARE FEET	×	MULTIPLIER	=	HEAT LOSS IN BTU'S
EXPOSED WALLS		PERIMETER × CEILING HT. = SQ. FT. _____ × _____ =	×		=	
GLASS	NO. OF WINDOWS NO. OF DOORS TOTAL GLASS	_____ × 15 = _____ × 20 = _____	×		=	
COLD CEILING		LENGTH × WIDTH = SQ. FT. _____ × _____ =	×		=	
COLD FLOOR			×		=	

TOTAL HEAT LOSS IN BTU'S NEEDED AT REGISTER OR RADIATOR ⇨

MULTIPLIERS

TYPE OF CONSTRUCTION		MULTIPLIERS FOR 70° AT OUTSIDE DESIGN TEMPERATURE						
		−30	−20	−10	0	+10	+20	+30
WALLS	FRAME OR BRICK VENEER STANDARD WALL							
	NO INSULATION	26	24	21	18	15	13	10
	WITH 2" OR MORE INSULATION	13	12	11	9	8	6	5
WINDOWS DOORS	PLAIN SINGLE GLASS	170	150	130	120	105	85	65
	WITH STORM SASH	80	70	60	55	50	40	30
CEILINGS	ATTIC ABOVE—NO INSULATION	32	29	25	22	19	15	12
	ATTIC ABOVE—3½" INSULATION	10	9	8	7	6	5	4
FLOORS	OVER BASEMENT (with furnace)	0	0	0	0	0	0	0
	OVER ENCLOSED CRAWL SPACE—4" INSULATION	5	5	4	4	3	3	2
	OVER ENCLOSED CRAWL SPACE—NO INSULATION	14	13	11	10	9	7	6
	OVER UNENCLOSED CRAWL SPACE	28	25	22	20	17	14	12
	ON A 4" CONCRETE SLAB	10	9	8	7	6	5	4

FIGURE 2.4

HEATING ESTIMATE WORK SHEET

TYPE OF HOUSE 1 STORY

○ ATTIC INSULATION ☒ YES ☐ NO
○ WALL INSULATION ☒ YES ☐ NO
○ STORM SASH ☒ YES ☐ NO

DESIGN TEMPERATURE
OUTSIDE -10 °F
INSIDE +70 °F
DIFFERENCE 80 °F

TYPE OF EXPOSURE		GROSS AREA IN SQUARE FEET				MULTIPLIER		HEAT LOSS IN BTU'S
EXPOSED WALLS		PERIMETER × CEILING HT. = SQ. FT.						
		148 × 8 = 1184				11		13,024
GLASS	NO. OF WINDOWS	10 × 15 = 150						
	NO. OF DOORS	2 × 20 = 40						
	TOTAL GLASS	190				130		24,700
COLD CEILING		LENGTH × WIDTH = SQ. FT.						
		46 × 28 = 1288				8		10,304
COLD FLOOR						0		0

TOTAL HEAT LOSS IN BTU'S NEEDED AT REGISTER OR RADIATOR ▷ 48,028

MULTIPLIERS

TYPE OF CONSTRUCTION		MULTIPLIERS FOR 70° AT OUTSIDE DESIGN TEMPERATURE						
		−30	−20	−10	0	+10	+20	+30
WALLS	FRAME OR BRICK VENEER STANDARD WALL							
	NO INSULATION	26	24	21	18	15	13	10
	WITH 2" OR MORE INSULATION	13	12	(11)	9	8	6	5
WINDOWS DOORS	PLAIN SINGLE GLASS	170	150	(130)	120	105	85	65
	WITH STORM SASH	80	70	60	55	50	40	30
CEILINGS	ATTIC ABOVE—NO INSULATION	32	29	25	22	19	15	12
	ATTIC ABOVE—3½" INSULATION	10	9	(8)	7	6	5	4
FLOORS	OVER BASEMENT (with furnace)	0	0	(0)	0	0	0	0
	OVER ENCLOSED CRAWL SPACE—4" INSULATION	5	5	4	4	3	3	2
	OVER ENCLOSED CRAWL SPACE—NO INSULATION	14	13	11	10	9	7	6
	OVER UNENCLOSED CRAWL SPACE	28	25	22	20	17	14	12
	ON A 4" CONCRETE SLAB	10	9	8	7	6	5	4

HOW TO USE WORK SHEET

There is only one "cold" ceiling — the one immediately below the attic. "Cold" floors are over an open area, on a concrete slab, or over an unexcavated area. Measure the length and width of these surfaces. When you have the measurements and other information filled in, figure the areas by multiplying the length times the width, as indicated on the work sheet.

Total area of exposed walls is the house perimeter (distance in feet around the outside) times ceiling height. For houses with more than one story, total the ceiling heights of all levels except basement, before multiplying by perimeter.

Multiply each of these areas by its indicated construction factor called a "multiplier" . . . to be found in the "MULTIPLIERS" Table on the work sheet. The answers will be in BTUs and will show the heat loss. Equipment is rated in BTUs, so if the total heat loss of the house is known, it is easy to pick a furnace or boiler of the proper size from the *Wards* Catalog.

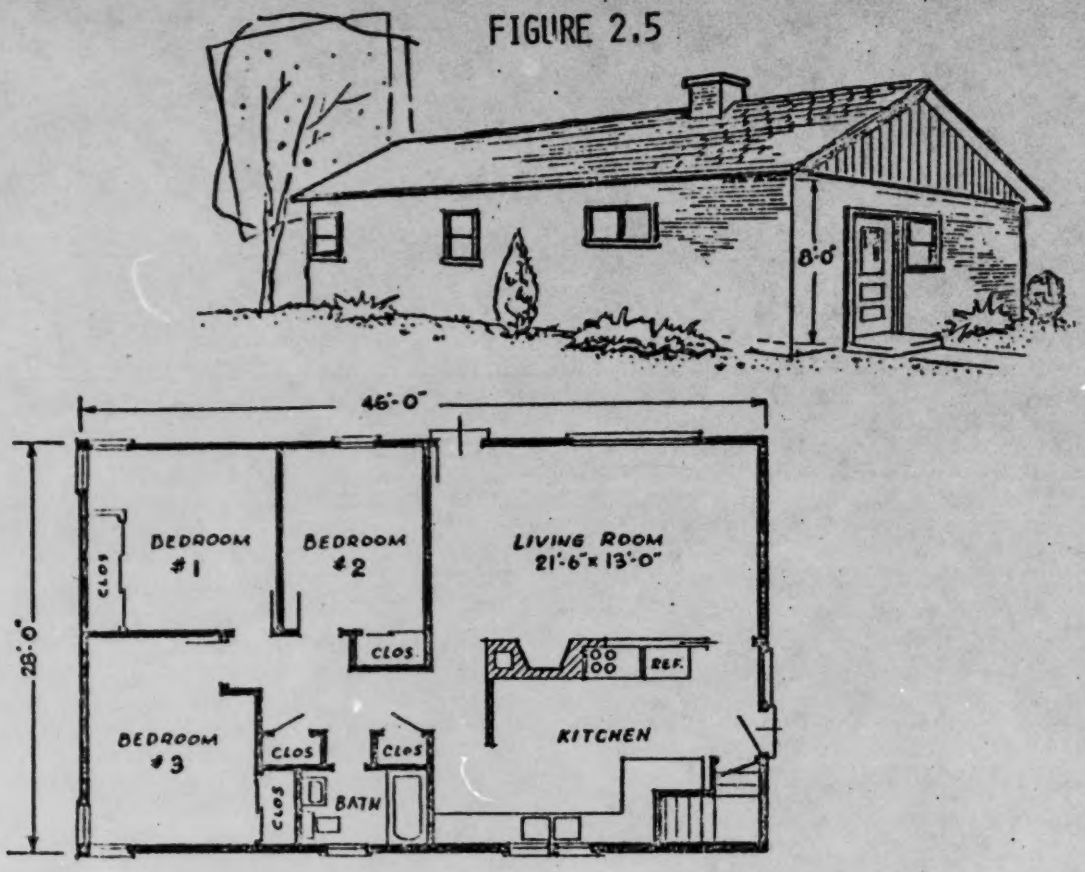
DETERMINING THE HEAT LOSS FOR A SAMPLE HOUSE

The Type of House

In estimating the heat loss of a sample house *(page 17)*, information and calculations are entered on the Work Sheet as shown above. Here is where they come from . . .

This is a single story house with a full basement. Both the walls and the attic have insulation, but the doors and windows are not protected by storm sash. The design temperature is -10°.

FIGURE 2.5



The Quick, Easy Calculations

WALLS Take the walls first. Walk around the house measuring its perimeter. In this example, it is 46 ft. *plus* 28 ft. *plus* 46 ft. *plus* 28 ft. or a total of 148 ft., which is entered on the form. Now, measure the ceiling height (8 ft). Multiplying these two figures (148 x 8) gives a total wall area of 1184 sq. ft.

Using the -10° column in the multiplier table, a figure of "11" is shown for insulated walls. Multiplying these figures (1184 x 11) gives a wall heat loss of 13,024 BTUs.

GLASS Count the number of windows (10) and multiply by "15." This gives a figure of 150 sq. ft. for windows. Similarly, count the number of doors (2) and multiply by "20" for a square foot figure of 40. Adding windows (150) and doors (40) gives a total glass area of 190. The multiplier for windows and doors without storm sash at -10° is "60". Multiplying these figures (190 x 130) gives the BTU heat loss of 24,700.

CEILING Ceiling area is the length of the house times its width (46 x 28) for a total of 1288 sq. ft. The multiplier for an insulated ceiling at -10° is "8." The heat loss of the ceiling then is (1288 x 8) or 10,304 BTUs.

FLOOR As the house has a full basement in which the furnace will be, the multiplier is "O". Therefore, the area of the floor need not be considered (since O x anything is still "O") . . . and the heat loss through the floor is nothing ("O").

TOTAL HEAT LOSS This is just the sum of the individual heat losses (13,024 plus 24,700 plus 10,304 plus 0) which is a total of 48,028 BTUs. This indicates the total amount of heat (in BTUs) that will be needed in the house. To obtain this amount of heat requires a furnace with an output rating (at the registers) of 48,028 BTUs, or more.

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C. FUEL COSTS

Once the heat load of a home has been established and the size of the heating system has been designed, the type of heating system to install must be determined. This question is predicted on the type of fuel available in a particular area and the fuel costs for operation.

All energy sources are bought in units, such as the gallon, the cubic foot, or the kilowatt-hour. The cost per unit doesn't tell what it actually costs to heat the house. To figure this one must know how much heat energy one can get from one unit of each energy source. That is, how many BTUs are produced from each unit bought. This information is given in Figure 2.6.

Be checking with local fuel suppliers find out the price of one unit of each type of fuel. Estimate your approximate fuel consumption for a typical winter heating month; then ask the fuel supplier what the cost would be so you can figure the average cost per unit.

FIGURE 2.6

COMMON FUELS AND THEIR HEAT ENERGY PER UNIT

FUEL	UNIT	BTU PER UNIT
natural gas	cubic foot	1,000
	therm (100 cu ft)	100,000
propane	gallon	90,000
butane	gallon	130,000
No. 1 fuel oil	gallon	136,000
No. 2 fuel oil	gallon	140,000
electricity	kilowatt-hour	3,413

Note: Propane and butane are gases that become liquids when they are pressurized, so they are sold by the gallon. Liquid petroleum gas (LPG) is a name commonly applied to both propane and butane, or even a blend of the two. In general, propane is used in the north while butane is used in the south.

Fuel costs can then be estimated by using the following formula:

$$C = \frac{F \times E}{P}$$

Where

C = cost per BTU of heat energy, in BTU per dollar

F = BTU value of fuel

E = efficiency of your heating system, in percent

P = price of fuel, in cents per unit

To illustrate how this formula is used, let's consider a house with an electric furnace having an efficiency of 90%, and located in a city where the utility company charges 2.5 cents per kilowatt-hour. Putting these numbers into the formula, we get:

$$C = \frac{3413 \times 90}{2.5} = 122{,}868 \text{ BTU per dollar}$$

As another example, let's consider a house with an oil furnace having an 80% efficiency and located in an area where No.2 fuel oil costs 40 cents per gallon. In this case, the formula tells us that the cost is:

$$C = \frac{140{,}000 \times 80}{40} = 280{,}000 \text{ BTU per dollar}$$

The fuel costs in these two examples do not tell the whole story. You would also have to weigh the cost of installing the particular heating system and any additional insulation you might add to your house. Then there is the question of what fuels are available in your area. So you can see there are actually many factors to consider.

The cost of the heat energy can give you a pretty good idea as to what fuels and heating systems would be more economical in your area. Just the number of BTU per dollar can tell you a lot. You could also estimate the heating bill by determining the heat load of a particular house for the average temperature difference during the winter heating season. Since the heat load is in BTU per hour, you would have to include the number of hours in each billing period

since there are no exhaust gases due to combustion. Electric baseboard heaters, for example, have an efficiency approaching 100% because practically all of the heat generated inside them is delivered to the area being heated.

FIGURE 2.7

HEATING SYSTEM EFFICIENCY

HEAT SOURCE	EFFICIENCY
wood furnace or stove	30-50%
coal furnace	30-60%
natural gas furnace	75-80%
propane furnace	75-80%
butane furnace	75-80%
oil furnace	75-80%
electric furnace	90-100%
electric baseboard	95-100%

1. FUEL FURNACE

Fuel furnaces must have flues to expel the combustion fumes, and unfortunately carry away large amounts of heat energy. Wood-burning units have the lowest efficiency rating-as much as 70% of the heat produced from the burning wood is wasted as it goes up the flue. Coal furnaces are almost as bad.

Therefore the damper that controls the flue has a lot to do with the efficiency of the heating system. Ideally, a fuel-burning furnace needs only enough air to assure that all of the fuel is cleanly burnt. Not enough air will prevent the fuel from burning completely, producing soot and dangerous carbon-monoxide fumes. Too much air, on the other hand, only cools the combustion temperatures and carries more heat up the flue. Hand-fed heating systems are therefore very inefficient because the damper setting must also be controlled by hand reducing the efficiency to about 30%. If an automatic feeder and automatic damper are added, however, the efficiency of these units can be increased to about 50%.

also be controlled by hand reducing the efficiency to about 30%. If an automatic feeder and automatic damper are added, however, the efficiency of these units can be increased to about 50%.

Natural gas, propane, butane, and oil furnaces have efficiency ratings of about 80%. If the gross input BTU to a furnace is listed as 100,000 BTU one would expect the net figure given as 80,000 BTU. But in practice, one could achieve a slightly higher not heating capacity with a finely tuned furnace-and a lot lower output with a poorly tuned one.

The higher efficiencies of gas and oil furnaces are due primarily to their construction. The amount of fuel fed into the furnace is carefully and automatically controlled when properly adjusted. The heat exchanger in such furnaces is also constructed to extract the maximum amount of heat energy from the hot gases produced as the fuel burns. Finally, the air flow through the combustion chamber is regulated by dampers to insure good combustion of the fuel. However, if the furnace is not properly adjusted and cleaned for maximum heat transfer, one cannot expect to obtain good heating efficiency.

If the air flow to the burner of a gas or oil furnace is not correct, the efficiency can drop to less than 50%. The flame of a gas furnace should be a bright blue color. If it is yellowish in color, the air flow could be adjusted too low or it may be that the gas pressure is too high; if the flame is erratic or jumps off the burner, the air flow may be adjusted too high or the gas pressure may be incorrect. When the adjustments are not correct on an oil-burning furnace, the flame smokes, causing problems with smut build-up in the flue or chimney.

Air flow through the heat exchanger in a furnace is also quite important. If the heating ducts or cold air returns are too small, the furnace will not deliver its rated heat capacity. A safety thermostat on the heat duct leaving the furnace prevents the air temperature from exceeding safe levels. If the temperature rises too high, the high-temperature-limit thermostat turns off the burners until the air temperature drops to a safe level again. If the burners on the furnace turn on and off even though the room thermostat is demanding more heat, that means the limit thermostat is operating, and this in turn indicates that there is probably not enough air flow through the ductwork.

Every forced-air furnace has air filters in the cold air intake to prevent dust particles from collecting in the furnace and ductwork. If dust collects in the burner box, it not only decreases heat conduction to the air, it also poses a fire hazard. If one smells scorched air from the heat registers, it is likely some dust has gotten into the burner box. A clean air filter will assure maximum air flow through the furnace.

The actual efficiency of a heating system will depend on several factors:

1. Properly adjusted burners.
2. Clean nozzles and jets.
3. Correct fuel pressure at the nozzles and jets.
4. Clean fuel filters.
5. Clean air filters
6. Properly adjusted nozzle and jet openings.
7. Correct size supply and return air ducts.
8. Well lubricated furnace blower.
9. Automatic (rather than manual) furnace operation.

If any of these factors are out of line, the efficiency of the system will drop, wasting both fuel and money.

2. ELECTRIC FURNACES

Electric furnaces resemble fuel furnaces but differ because no combustion takes place. As a result, there are no burner adjustments to make and no flue pipe to waste heat. An electric furnace, therefore, requires little maintenance to keep the unit operating at maximum efficiency of 90-100%.

Electric furnaces, however, have much in common with fuel furnaces when it comes to the ductwork and blower that circulates the heated air throughout the house. For this reason, most of what has been said about the size of the ducts, clean air filters, and routine maintenance also applies to electric furnaces.

Because of the relatively high cost of electricity as compared to other fuels, the efficiency of an electric furnace system is of paramount concern. Heat losses cannot be tolerated, and every step must be taken to thoroughly insulate and seal the home. Most of the heat loss occurs in the duct system, so it is important to properly insulate and seal ducts passing through garage areas and open crawl spaces. Most all-electric homes are built with considerably more insulation than other homes to offset the higher cost of electricity, so adding more insulation to the house is usually a good idea.

3. HEAT PUMPS

A heat pump is the most efficient type of mechanical heating system. A heat pump does not have to burn fuel to produce heat, and it does not have to waste electrical energy by running it through a resistive wire element to produce heat. The heat pump only requires enough electricity to run a compressor motor, which takes the heat out of the air on the outside of the house and deposits this heat inside the house.

The heat pump is actually a kind of refrigeration or air-conditioning system that can work in reverse. In the summer, the heat pump cools the house in the usual manner, removing heat from within the house and depositing it outside. In the winter, the heat pump works in reverse, removing heat from the outside and depositing it inside.

The efficiency of a heat pump is measured in terms of how much easier it is to pump heat energy than to generate it by conventional means. When used to heat a house, the efficiency of a heat pump depends primarily on how cold it is inside. As the temperature drops, the efficiency also drops. If it gets too cold outside, the heat pump automatically switches on an electric heating element, when it becomes easier and more economical to generate heat energy that way. Normally, though, as long as the outside temperature is above about 20°F, the heat pump can heat the house more cheaply than an electric furnace. As the outside temperature approaches the inside room temperature, the efficiency continues to climb dramatically.

Taken on a year-around basis, a heat pump can usually heat a house for a third of half the cost of conventional electric heat. In a northern city like Cleveland, Ohio, for example, the annual heating cost for a heat pump is about 50% of that for an ordinary electric furnace, making the heat pump cost-competitive with natural gas in that area. In southern states, operating efficiency is much higher because outside temperatures are higher.

Heat pumps cost substantially more to purchase and install than conventional heating systems with central air conditioner. Manufacturers and representives claim, however, that the heat pump can greatly reduce the heating bill, so it would not take long to make up the difference in the original purchase price. Keep in mind, though, that the location has a lot to do with the cost savings. As long as the winter temperature in an area stays high enough, the heat pump will save quite a bit on a heating bill. As the temperature drops so do the savings. At lower temperatures, the electric resistance heat is turned on automatically to assist the heat pump.

4. ELECTRIC BASEBOARD HEATERS

An electric baseboard heater may operate at nearly 100% efficiency, since there are no fans and no duct system to waste heat. This assumes, however, that the unit is wired properly and is perfectly clean. The efficiency of a baseboard heater will be reduced if the heating element gets dirty. Reducing the transfer of heat that should go into the room. Baseboard heaters should be cleaned with a vacuum cleaner at least once a year to avoid this problem.

E. MAINTENANCE

1. FILTERS

All central heating systems have filters. These filters all get dirty-that's their job! They take the dust and lint particles out of the circulating air so dirt does not clog up the working parts of the furnace. The air filter is usually located in the return air duct where the cool air enters the furnace to be heated. As the filter removes the dirt from the air, the filter itself becomes clogged and restricts the air flow, cutting down on both the efficiency and capacity of the furnace. Filters should be checked every month and either cleaned or replaced.

2. FANS

The fan most used in heating systems is the squirrel cage fan. This fan circulates the air through the furnace and duct system. Over a period of time-even with regular filter replacements-the blades and motor of the fan will become covered with dirt, reducing air flow in the furnace. Clean the fan blades with a brush and soapy water. Be careful not to move any of the balance weights from the fan blades.

3. ADJUSTING LPG AND NATURAL GAS FURNACES

A gas furnace may burn natural gas (methane), propane gas, or butane gas. Natural gas is delivered to the house through underground gas lines, while liquid petroleum gas (LPG) is stored near the house in supply tanks with direct feed lines to the furnace. The gas flow to the furnace is regulated by a gas valve in the line, which meters the amount of gas entering the burners within the heat exchanger. Air is mixed with the gas there and is ignited to produce heat.

To get the highest amount of heat energy from the furnace, the gas and air mixture must be just right. To accomplish this feat, a series of regulators control the flow of gas to each burner, and each burner has an adjustment mechanism to control the air flow.

a. Gas Valves

The manifold is a pipe that connects between the gas valve and the burners. Gas flows from the valve into the manifold, which distributes the gas to the burners. The purpose of the gas valve is to control the flow of gas into the manifold. When the furnace is not heating and the thermostat is not calling for heat, the gas valve is closed. When the thermostat calls for heat, an electrical solenoid in the gas valve opens, permitting gas to flow through the valve into the manifold.

If the pilot light goes out, the gas valve is shut off to safely prevent gas from escaping into the furnace room and house. The gas valve closes when the pilot light goes out because the thermocouple, a temperature-sensing device, is no longer heated by the pilot light.

If the gas valve leaks, gas can enter the furnace and room even when the pilot light is off. This not only wastes gas and money, it can also be very dangerous, leading to fire or explosion. Therefore, check for gas valve leaks.

b. Adjusting the Air Mixture

The flame should be a bright blue color close to the burner. If the flame is not burning correctly, the first place to check is the air adjustment. When

there is not enough air, the flame will usually have a yellowish color. This means the flame is not burning hotly, so it will take more gas than it should to heat an area. Too much air causes the flame to burn with a pale blue or white color.

c. Cleaning the Burners

If the air flow is out of adjustment on the burners for a long time, soot may collect around the burners. The flame may even burn inside the burner body or at the gas jet opening and build up carbon and soot inside the burner. Sometimes dust and lint in the air will also collect in the throat of the burner and partially block the air flow. In damp locations, the burner can become spotted with rust.

Clean the burners with compressed air to remove dirt, lint, and loose soot. If the burners are oily, wipe them carefully with a cloth, but be careful not to bend or break the burners. As a last resort, if there are some really tough buildups of soot, use a cleaning solvent to dissolve the dirt.

d. Adjusting the Gas Pressure

The gas pressure also affects the mixture of the gas and air going to the burners. If one has tried adjusting the air flow to the burners, has cleaned the burners, is sure that all gas connections are tight, and still has a flame that does not burn properly at the burners, the gas pressure may not be correct. A sure indication of pressure problems is a flame that is too large or too small.

To measure gas pressure, a special gauge is used that measures the pressure in inches of water, indicated by the height of the water column in a glass tube. Gas companies and repair services have them. Do not attempt to adjust the gas pressure without using the proper set of gauges.

e. Adjusting the Pilot Light

The pilot light in most gas furnaces is on all the time, though some new furnaces use a form of electric ignition. Before adjusting the pilot light, it's a good idea to inspect it to insure that it is reasonably clean. A dirty or clogged pilot is often responsible for the pilot light going out, and a pilot light that is too small often causes noisy ignition of the burners. To clean the pilot light, remove it from the burner assembly.

Some forms of electric ignition use a hot wire to ignite the pilot, which then heats the thermocouple, which in turn allows the burners to turn on. Oil furnaces generally use arc igniters to light the fuel. Electric ignition systems can save fuel, but they have their problems too. In hot-wire systems, for example, the wire element can fail, but this is easily replaced with a new unit. An advantage of such systems is that the pilot and thermocouple parts are not on most of the time, so they do not have to be cleaned or adjusted as often.

4. ELECTRIC FURNACES

An electric furnace will usually operate properly and at maximum efficiency for many years without adjustment. Since there is no fuel combustion taking

place, there will not be problems with carbon and soot buildup. So any dirt that could decrease efficiency in an electric furnace must come from the air circulated inside the house. Keeping the air filters clean is therefore an important part of maintaining an electric furnace. Since there is no combustion, the electric furnace also has no flue to waste heat energy. As a result, almost all of the heat produced by the furnace elements ends up in the house.

Heat is generated in an electric furnace by passing electric current through resistance wires. When these heating elements raise the temperature of the air enough in the heat chamber, the fan starts and circulates the warm air throughout the house. These electric heating elements draw a lot of electrical power, so it is essential that adequate sized wires are run to the furnace to supply all the current it needs. Normally, the local building codes insure that the proper size wiring is used, since the current passing through these wires also produces heat, which is wasted.

a. Maintaining the Fan

The fan controls on an electric furnace are usually preset and cannot be adjusted. The switches that turn the fan on and off, for example, are sealed units mounted in the heat chamber. The limit switch is usually a metal fuse (rather than a circuit breaker), and melts when the furnace elements get too hot. Consequently, if the fan does not come on for some reason, the fuse will open, requiring that it be replaced after the fan is fixed.

About all one can do in an electric furnace is to keep the fan blades, fan motor, and filters clean. If one allows a regular maintenance schedule, there should be few problems with the furnace.

b. Checking the Thermostat

An electric furnace usually has a special two-stage thermostat that prevents waste of energy. For example, consider an electric furnace with four heating elements. When the thermostat calls for heat, the first two elements come on immediately. The second two elements will not turn on unless the thermostat senses a big drop in temperature or unless the last two elements do not heat the house fast enough. This technique gives some energy savings to the homeowner because the second two elements are not used until they are needed.

Sometimes an outside thermostat is also attached to the two-stage thermostat inside the house. In this system, if the temperature outside remains above a preset temperature usuaully about 35°F), the second stage of the thermostat cannot come on.

F. HUMIDIFIERS

Relative humidity is the percentage of moisture in the air relative to the amount of moisture that the air could hold at that temperature. People generally feel uncomfortable when there is too much or too little moisture in the air. During the summer, for example, a relative humidity of more than 70% makes the air feel damp, close, and sultry. During the winter, a relative humidity of less than 30% makes the air feel dry, irritates the nose and throat, and encourages the buildup of static electricity in rugs,

Proper humidification is very important with respect to maintaining a comfort index at a comfort level within the structure. If one has proper humidity the comfort temperature can be dropped from 70 to the mid-60's without any noticeable change in perceived comfort. If the air is dry then the room will feel cold in the mid-sixties plus the simple fact that static electricity is highly uncomfortable in any social interaction.

upholstery, and clothing. Dry air also makes the air feel cooler because it speeds up the evaporation of moisture from the body.

During the heating season, it is difficult to maintain a suitable level of humidity because the air outside the home contains very little moisture. For example, if the temperature is 50°F outside with 100% relative humidity, the humidity will drop to less than 20% by the time the air has been heated to 70°F. For outside temperatures below freezing, the air contains practically no moisture to speak of. For this reason, the relative humidity in your home will go way down during the coldest winter months.

Many schemes have been tried for increasing the humidity level in a home during the winter. You can boil pans of water on the stove, hang up wet cloths in the basement to dry, drape wet towels over radiators, set water-filled pans on the floor, etc. But if not inefficient, these methods are messy to say the least. Most modern furnace humidifiers require a minimum of maintenance, and a selection of models is available in a wide price range.

All humidifiers should be inspected once a year before the heating season begins. Evaporator-type humidifiers should also be inspected a couple of times during the winter to be sure that accumulations of lime and minerals from the evaporating water do not clog the water-inlet valve or the fins, belts, and bristles.

As water is evaporated from the humidifier, lime and mineral deposits are left behind. These collect on the valve seat, so they

must be removed periodically. If they are not, the valve may not turn off, causing the water basin to overflow.

To clean the humidifier, first remove it from the bottom of the duct. You can drain the water from the basin of the humidifier through the drain hole in the bottom. Scrape all the mineral deposits from the float, the valve, and the valve seat. Remove the mineral deposits from any other part of the humidifier and water lines.

1. OPERATION AND MAINTENANCE

-Read the owner's manual.
-Place the unit near a room partition and allow 6 inches behind it for circulation.
-Avoid small rooms, heat sources, and corners. The bottom of a stairway is a good location.
-For the first few days, adjust at high settings to moisten air, walls, and furniture. Turn down as dampness develops.
-Set humidistat at a level for personal comfort.
-Disconnect the unit when filling or cleaning the water reservoir. Be sure the area and unit are dry before reconnecting the cord.
-Do not pour hot water in the reservoir or overfill it.
-Dust the grilles every week with a soft brush.
-Every few weeks, empty the reservior and scrub the inside with a sponge and a mild detergent to prevent mold, mildew, and bacteria.
-Clean the filter pad monthly.

2. FUEL SAVINGS

For years it has been common knowledge that people feel warmer when the humidity in a room is higher. Generally, you can figure that each 10% increase in relative humidity enables you to turn down the room thermostat by about one degree. This would seem to indicate that you can obtain a substantial fuel savings by using a humidifier in your home. But you have to be careful about such claims because the savings are not as great as some manufacturers would have you believe.

You will remember that when water evaporates it absorbs heat energy. Your furnace has to supply this heat energy when you use a humidifier-and it takes over 8000 BTU to evaporate just one gallon of water. Fortunately, however, the average size home needs less than one gallon of water evaporated into the air to bring the relative humidity from 0% up to 50%. Since there are many other sources or water vapor in your home, your furnace humidifier does not have to supply very much water each day to maintain the humidity at a comfortable level. Of course, this depends upon how much infiltration air enters your home, pushing out the moist air. The more tightly sealed your home is, the more moisture it will be able to retain, and the less water vapor your humidifier will have to add to the air to replace what was lost.

As an example of cost, let's use the home in Chapter 6 that had an average heat load of 25,000 BTU per hour over a six-month heating seaons. During the average 24-hour day, this furnace would consume 600,000 BTU of heat energy, and assuming that the humidifier used up a whole gallon

of water in that time, 8000 BTU of heat energy would be needed to evaporate the water. Now, if having a 50% relative humidity inside the house would permit you to turn down the thermostat just two degrees, the furnace would consume 30,000 BTU less energy on a day that the outside temperature was 40 degrees less than the inside. Clearly, the 8000 BTU expended in evaporating the gallon of water saved you quite a bit of fuel energy. In general, the energy savings will pay for the furnace humidifier in about two to five years, depending on how much moisture you have to add to the air in your home and how expensive the unit was.

G. SPACE HEATERS

For a small house or apartment in areas with mild winters, a heating unit such as a wood stove, coal stove, fireplace, gas heater, oil heater, propane heater, or electric space heater can be more economical than a central furnace.

When choosing a space heater, keep safety and energy use in mind. Electric heaters should be considered last because they are heavy users of energy. Non-electric heaters should be properly vented. If venting is inadequate or the adjustments faulty, deadly quantities of carbon monoxide may be produced. Many states prohibit unvented units because of this hazard.

A space heater should have a guard around the flames or coils to protect children, pets, and clothing from the heat source. Allow adequate clearance on all sides of the unit.

To keep the heater in good working order, inspect it regularly for needed adjustments, cleanliness, cracks, faulty legs, and hinges. Keep the electrical wiring in good condition.

For Safe Operation of Space Heaters

-Keep a window partially open if an unvented unit must be used. Fresh air will prevent the accumulation of gas fumes.

-Use only the fuel the heater is designed for. Do not convert to another fuel without consulting an expert.

-Keep children away from space heaters and stoves.

-Be certain the fire has proper ventilation to maintain a constant rate of burning that gives moderate heat, not too hot or too cool.

-Always keep a screen around a heater that has open flames.

-Keep the damper open while the fuel is burning. This will provide for efficient burning and will prevent accumulation of explosive gases.

-Learn how to light a gas heater properly. If someone smells gas, turn off all controls and open a window. Don't allow gas to accumulate. If heater fails to light on the first try, allow sufficient time for the gas to dissipate before trying again.

-Never keep flammable liquids around heaters. Vapors can be ignited by the open flames.

-Use heavy-duty cord for electric heaters. Have an electrician check the wiring if a heater uses higher than usual wattage.

-Never place an electric heater near a bathtub, shower, or sink. Don't touch one when wet.

-Place a metal sheet under the unit to protect the floor from live coals, burning or overheating.

The fireplace is used today primarily as an enjoyable addition to a house. Watching the flames can bring peace to the heart and soothe the soul. Even more importantly, however, the fireplace can be used to supplement central heating. On cool days, the fireplace might provide the necessary heat to take away the chill.

The most energy-efficient fireplace will have warm air vents through which hot air can be spread around the room or through ducts to other rooms. A modified fireplace with a fan can also help circulate hot air effectively.

To obtain maximum efficiency from a fireplace, be sure the chimney is working as it should. If the chimney is too low, the draft will not be strong enough to pull out the smoke. Keep the chimney clear of ashes and be sure the flue is operating properly.

H. ENERGY SAVING TIPS IN HEATING

The U.S. Department of Energy has outlined tips for saving energy in heating. This list serves as a summary of conservation measures available to the homeowner when considering heating the home.

Heating and cooling our homes account for most of our residential energy costs. Don't waste any of that precious conditioned air, whether you pay for it yourself or pay your landlord for it.

During both heating and cooling seasons. . .

-Close off unoccupied rooms and shut their heat or air conditioning vents; or turn off room air conditioners. (This does not apply if you have a heat pump system. Leave it alone; shutting vents could harm a heat pump.)

-Use Kitchen, bath, and other ventilating fans sparingly. In just 1 house these fans can blow away a houseful of warmed or cooled air. Turn them off just as soon as they have done their job.

-Keep your fireplace damper closed unless you have a fire going. An open damper in a 48-inch square fireplace can let up to 8 percent of your heat out the chimney.

Heating Energy Savers

Don't turn the heat on until you have to. On cool evenings use your fireplace instead and add a blanket at night.

With heating equipment. . .

-If you use electric furnace heating, consider a heat pump system. The heat pump uses thermal energy from outside air for both heating and cooling. Costs for these pumps run from about $2,000 for a wholehouse unit to about $425 for room size. But they can cut your use of electricity for heating by 30 to 40 percent and also can provide some savings in cooling costs.

-If you plan to buy a new gas heating system, ask your gas utility or public service commission about the savings potential of electronic ignition. Ask also about possibilities for retrofitting the system you may already own.

-Consider the advantage of a clock thermostat for your heating system. The clock thermostat will turn the heat down for you automatically at a regular hour before you retire and turn it up again before you wake. While you can easily turn your thermostat back at night and up again in the morning yourself, the convenience of a clock thermostat may be worth the $70 to $90 cost to you.

-Consider buying a properly sized furnace that incorporates an automatic flue damper. This device reduces the loss of heat when the furnace is off. (Contact your gas utility or oil supplier for guidance.)

-Don't use your fireplace for supplemental heating when your furnace is on unless you take one of the measures suggested below to lessen the loss of heated air from the house.

The warmth from a fire on the hearth generally doesn't radiate through the house; the heat gain is confined to the room with the fireplace. And when your furnace is on, too, a considerable amount of heated air from the rest of the house flows into the fireplace and goes wastefully up the chimney. Then the temperature in other rooms of the house goes down, and the furnace uses more fuel to raise it to the level controlled by the thermostat. So you use more fuel, rather than less, when the furnace and fireplace are both going.

Lessen heat loss when you use your fireplace when the furnace is on:

-Lower the thermostat setting to 50 to 55 degrees. Some warmed air will still be lost, but the furnace won't have to use as much fuel to heat the rest of the house to these temperatures as it would to raise the heat to 65 degrees.

-Close all doors and warm air ducts entering the room with the fireplace and open a window near the fireplace about 1/2 to 1 inch. Air needed by the fire will be provided through the open window and the amount of heated air drawn from the rest of the house will be reduced.

-If you have a simple open masonry fireplace, consider installing a glass screen. This will cut down on the loss of warmed air through the flue.

When the heat is on . . .

-Lower your thermostat to 65 degrees during the day and 55 degrees at night. You can save about 3 percent on your fuel costs for every degree you reduce the average temperature in your home. In addition, you can save about 1 percent on your heating bills for every degree you dial down only at night.

-Keep windows near your thermostat tightly closed, otherwise it will keep your furnace working after the rest of the room has reached a comfortable temperature.

-Have your oil furnace serviced at least once a year, preferably each summer to take advantage of off-season rates. This simple precaution could save you 10 percent in fuel consumption.

-Clean or replace the filter in your forced-air heating system each month.

-Check the duct work for air leaks about once a year if you have a forced-air heating system. To do this, feel around the duct joints for escaping air when the fan is on.

-Relatively small leaks can be repaired simply by covering holes or cracks with duct tape. More stubborn problems may require caulking as well as taping. You could save almost 9 percent in heating fuel costs this way.

-If you have oil heat, check to see if the firing rate is correct. Chances are it isn't. A recent survey found that 97 percent of the furnaces checked were overfired.

-If your oil furnace doesn't run almost constantly on a very cold day, call a service man.

-Don't let cold air seep into your home through the attic access door. Check the door to make sure it is well insulated and weather-stripped, otherwise you'll be wasting fuel to heat that cool air.

-Dust or vacuum radiator surfaces frequently. Dust and grime impede the flow of heat. And if the radiators need painting, use flat paint, preferably black. It radiates heat better than glossy.

-Keep draperies and shades open in sunny windows; close them at night.

-For comfort in cooler indoor temperatures, use the best insulation of all-warm clothing.

The human body gives off heat, about 390 BTU's per hour for a man, 330 for a woman. Dressing wisely can help you retain natural heat.

-Wear closely woven fabrics. They add at least a half a degree in warmth.

-For women. Slacks are at least a degree warmer than skirts.

-For men and women. A light long-sleeved sweater equals almost 2 degrees in added warmth; a heavy long-sleeved sweater adds about 3.7 degrees; and two lightweight sweaters add about 5 degrees in warmth because the air between them serves as insulation to keep in more body heat.

If every household in the United States lowered its averge heating temperatures 6 degrees over a 24-hour period, we would save more than 570,000 barrels of oil per day or more than 3.5 percent of our current oil imports.

UNIT III

COOLING SYSTEMS

OBJECTIVES: Upon completion of this unit the student will be able to:

a. Identify the components of a typical air conditioner.

b. Distinquish between the uses of room air conditioners and central air conditioning systems.

c. Calculate and size an air conditioner for a particular cooling need.

d. Discuss maintenance and use tips for efficient air conditioning performance.

e. Discuss the role of dehumidifiers in summer cooling.

LECTURE

LABORATORY

INTRODUCTION:

There are several types of air-conditioning systems for cooling the home during the hot summer months: a wide range of air conditioners, central air conditioners, or heat pumps. All of these systems work in essentially the same way, and all require similar maintenance to keep them working at top efficiency.

Most homes built today have the capability of easy conversion to central air conditioning, if they do not already have it. Homes built with heat pumps to provide heat during the winter also use the same unit to provide air conditioning during the summer. Most room air conditioners are used today where only one or two rooms are to be cooled, or where central air conditioning

is impractical or unnecessary. So the type of air conditioning one has or wants depends on the cooling needs and the cost of installing a particular system.

A. AIR CONDITIONER COMPONENTS

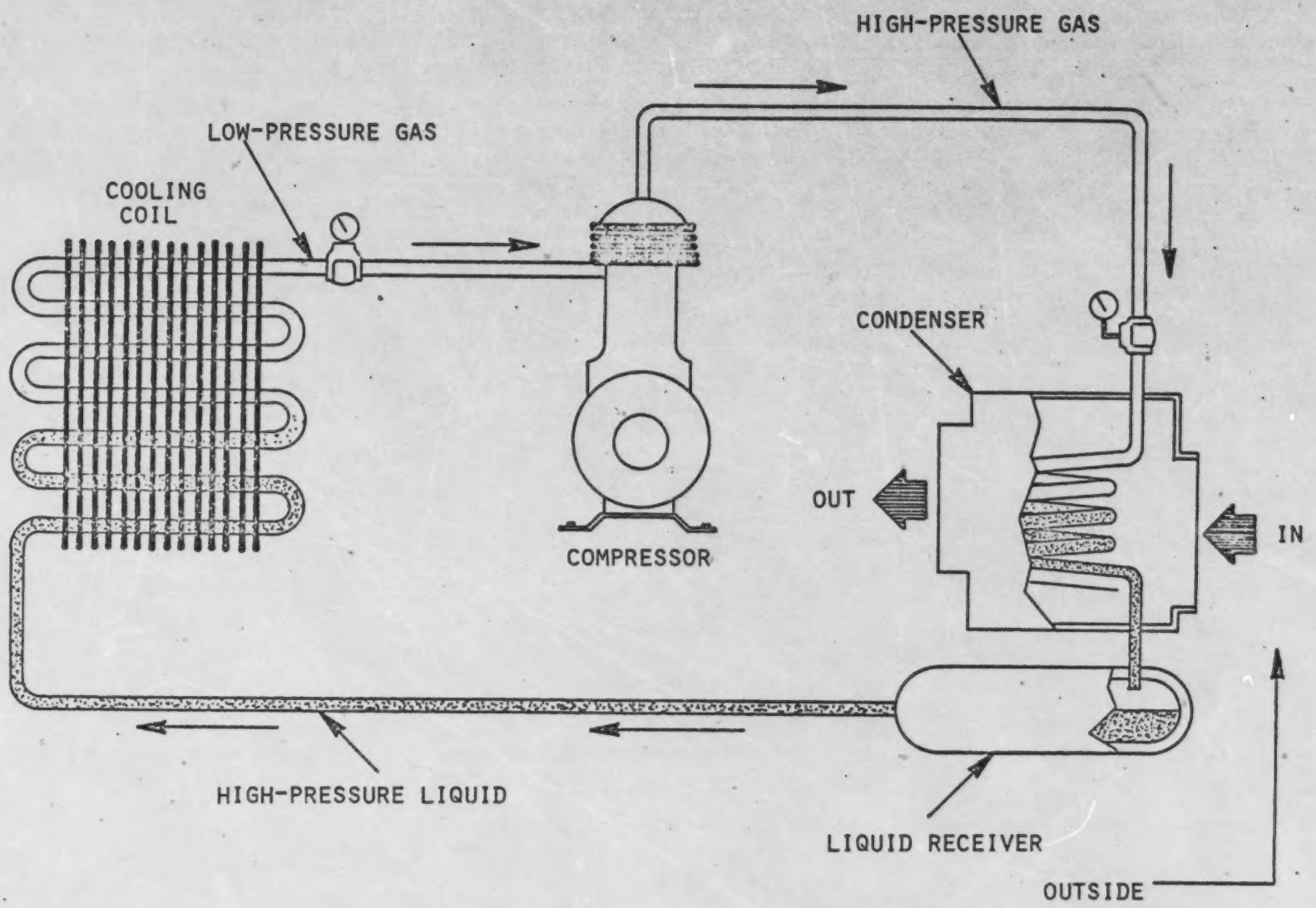
An air conditioner cools air much as a refrigerator cools the air inside it. The principal difference is that an air conditioner is designed to have the cooled air blown through the cooling coil and out (through whatever distribution system is used) into the house. . . then back (through return-air system) to the coil for recooling. While cooling the air, the coil condenses the moisture carried by the air, and the resulting water runs off through a water line to leave the air less humid.

Whatever type the air conditioner is, it has the functional parts illustrated in Figure 3.1. A blower-coil or a self-contained unit has, in addition, an electric-motor-driven blower to circulate house air through the cooling coil. The refrigerant, which circulates around from the cooling coil to the compressor to the condenser, and back to the coil, is a volatile liquid (such as Freon) which changes from gas to liquid and back to gas as the pressure and temperature to which it is subjected changes.

Gas (at low pressure) moves from the coil to the compressor, where it is compressed and forced on to the condenser in the form of a hot gas or vapor. Here the hot gas is cooled (by outside air) and becomes a liquid. This liquid, still under pressure, travels to the cooling coil where it is allowed to expand (pressure is relieved) into a gas again. While expanding it absorbs heat to keep the coil relatively cold...and

Thermostat control provides one of the easiest ways of maintaining the house in a comfort system and reducing the amount of energy necessary. Thermostats can be single or can be multiple with some sort of switching option. In thermostat control the first basic thing is to decide what your schedule is, when you will be in the home, out of the home, and adjust the desired base line temperatures accordingly. Most people do not think to turn thermostats down when they leave or to turn thermostats down at night. But, by this choice of options using some sort of programmed clock thermostat which can either be day or nighttime or which can be a seven-days thermostat. An appreciable savings of maybe 10-15-20% can be made in the overall fuel cost and utility bill by just turning the furnace down at night shall we say to 60-64°F and may be maintaining it in the day at about 68-70°F. Obviously, when one is out of the home completely, the furnace can be turned down to the lowest setting for periods where one will be gone more than 6-8 hours.

FIGURE 3.1 AIR CONDITIONING SYSTEM



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thereby cools the house air blown through this coil. A thermostat can be used to control compressor operation and/or blower operation to maintain desired house air cooling.

B. TYPE OF AIR CONDITIONERS

1. Room Air Conditioners

A room air conditioner can be installed either in a window or wall. There are many different models, designs, and styles of room air conditioners available ranging in size from small units able to cool just one room, to large units used to cool three or four rooms. Large units are often mounted through the wall and become permanent installations.

The big selection of air conditioners introduce a lot of problems. First, one must check the power consumption outlets, and voltages required by the various air conditioners. Then one must be concerned about the cooling capacity of the air conditioner to insure that it meets particular needs.

One of the biggest reasons an air conditioner does not perform to expectations is that the unit is simply too small for the area being cooled. The opposite problem of course, occurs when a person buys an extra-large air conditioner, one that has much more cooling capacity than is needed. A large unit makes too much noise, produces drafts, cools the room too quickly, or does not seem to be able to lower the humidity of the air. All of these are common problems with oversized air conditioners, proving that bigger is not always better.

A large number of people buy a room air conditioner with the idea of cooling more than one

room. The problem here may be improper air circulation. Cold air is heavy and difficult to move; it has a tendency to sink down next to walls and lie on the floor. A room air conditioner can provide only limited air circulation. It has a fan to blow the air out into the room, but it has no way to really circulate the air through the house. Cool air will not circulate by itself as readily as warm air, so you have to be sure that either the air conditioner's fan is able to blow the cool air into all rooms or provide an extra fan to assist the air conditioner.

If the air conditioner is installed in a room that has limited circulation to the other rooms in the house, like a bedroom, the room with the air conditioner will be much cooler than the other rooms. Using fans to help circulate the cool air can bring the air conditioner's performance up to what it should be. Fans are beneficial in another way, for the air circulating from the fans will speed up evaporation from the body and make one feel cooler. He/she will probably by able to turn the thermostat on the air conditioner to a warmer setting and save some electricity.

The performance of a room air conditioner depends a good deal on the place in the home chosen tc have it installed. For example, if the air conditioner is installed in a window directly opposite a door, the fan on the air conditioner is going to blow cool air out the door each time it is opened. Certainly, this is no way to conserve energy and cool a room efficiently.

If a person wants to cool two or more rooms, it is desirable to locate the air conditioner opposite an open doorway to one of

for good cooling. In general the cooler the air around the condenser, the more efficiently the air conditioner will perform.

Size is very important. If an air conditioner is too small, the air conditioner will run continuously on hot days and still not be able to cool the room. On the other hand, if the air conditioner is too large, the unit will start up and cool the area so quickly that it will only be on a short time. Given the large amounts of electricity needed to start an electric motor and bring the air conditioner up to normal operation, the more often the compressor motor has to start, the more electricity will be wasted. Another result of short operation times is that the humidity in the room will not be lowered as much, and this means the thermostat has to be set a lower temperature for comfort, wasting more electricity.

Window air conditioners are sized in three ratings: horsepower, BTU, and tons of refrigeration (12,000 BTU is equal to one ton of refrigeration. A one-horsepower unit provides about 8000 BTU depdning on the efficiency of the unit.

An average size room with good insulation will usually require a unit rated at 8000 BTU, or 3/4 ton. A one-ton air conditioner is usually large enough to cool two rooms, while a two-ton air conditioner will usually cool four or five rooms. These estimates depend, of course, on the air circulation in the house, its construction, insulation, and location.

As a rough estimate, one will need from 2.5 to 3 BTU for each square foot of floor space in a well insulated room. Before purchasing a room air conditioner,

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measure the floor area of the rooms to be cooled. Also measure the window area and make a note of how much window area faces north, south, east, and west, and whether or not the windows are shaded. Make a note of the number of appliances operating in the room and their wattages. Armed with these figures estimate the right size unit for your needs. (See section of this unit which shows how to estimate cooling needs.)

Before going out to buy a room air conditioner check the wiring. While very small room air conditioners (4000 to 5000 BTU capacity) are not likely to require special wiring, air conditioners rated at 6000 BTU or more draw a considerable amount of electric current when they are starting up and operating. Therefore, be sure that the wiring in the home can handle the load.

Older homes often have circuits that can handle no more than 10 amperes, while most homes today have circuits rated for 15 or 20 amperes. A 6000 BTU air conditioner will typically require between 6 and 8 amperes, so even this relatively small unit will use a large percentage of the current capacity in one circuit of your home.

Large room air conditioners normally require 240V instead of the usual 120V found in most home outlets. The reason for this is that 240-volt operation needs only half as much current to produce the same amount of power. Air conditioners are primarily 120-volt units until their current demands approach about 12 amperes; above this they normally use 240V. In terms of cooling capacity, this transition occurs somewhere between 8000 and 12000 BTU, depending on the efficiency of the

unit and on whether or not 240V is available. When air conditioners come in either 120V or 240V, the 240V-volt unit is generally more efficient because the lower amount of current also wastes less energy in the motor wiring.

2. Central Air Conditioning Systems

A central air conditioning system operates the same way as a room air conditioner. The components are the same and the operation is the same. A central air conditioner merely has larger parts and capacity and is designed to cool an entire house instead of one or a few rooms.

The evaporator coil is usually cased in the furnace component. The condenser is outside the house, connected to the evaporator by copper tubing carrying the refrigerant back and forth. An alternate type of central air conditioner is made as one unit, located outside the house and connected to the furnace duct system through a separate duct line. (Refer to Figure 3.1 for an illustration of the components discussed.)

C. SIZING A COOLING SYSTEM

FIGURE 3.2
DESIGN TEMPERATURES FOR AIR CONDITIONING
(OUTSIDE DRY AND WET BULB TEMPERATURES)

	Summer DB	Summer WB
TEXAS		
Abilene	95	74
Amarillo	95	72
Austin	100	78
Brownsville	95	80
Corpus Christi	95	80
Dallas	100	78
Del Rio	100	78
El Paso	100	69
Fort Worth	100	78
Galveston	95	80
Houston	95	80
Palestine	100	78
Port Arthur	95	80
San Antonio	100	78
Waco	100	78

In addition to the thermostat control on a single basis, some adjustment in thermostats with manual overrides for specialty thermostats in rooms where zonal living options are used should be considered if one is developing an integrated conservation package. In zonal living, internal insulation and thermal barriers are used to keep heat flow from the rooms being occupied to the non-occupied rooms to a minimum. This is a fairly complex concept because one must be sure that water pipes and other internal objects that freeze are isolated or kept within the zonal living area of optional use so that they do not freeze on sudden or great temperature drops. This means that even though the internal rooms may be allowed to drop to 40-45°F it is possible for water pipes in outer walls in areas where the temperature drops to below zero to freeze under this option. This is especially true where one has gone for heavy insulation. The thermostat control for zonal living means that a person does one of two things. He either turns the main thermostat down and has adjusted the registers according to some predetermined plan to maintain a desired room or rooms at a fixed temperature as a function of what the temperature would be at the thermostat under this option. This involves a lot of trial and error with respect to setting thermostats and taking temperatures. However, if time is not of essence and money is not available this is the viable option.

As with a heating system, "sizing" means simply the selection of cooling equipment that will have the right capacity (in BTU's) to properly cool a home. If there is a forced-air heating system already, adding central air conditioning for summer use will already include the necessary ductwork, etc. for distribution of the heated (or cooled) air. The only additional equipment to be selected will be the air conditioning unit (which will be installed as part of the heat-cooling system). However, if only for a central air-conditioning system (without central heat), is desired, the cooling equipment must also include the necessary ductwork and registers.

Many people believe that comfort cooling calls for lowering the house temperature by 12° to 15° below the outdoor temperature, and that's all. This is an error.

Regardless of the outdoor temperature in summer, the indoor temperature should be in the neighborhood of 78°, and the relative humidity should be about 50%. If it is any hotter or more humid than this, the overwhelming majority of people will feel distinctly warm and uncomfortable, whether the outdoor temperature is 85° or 100°. Thus 75° and 50% relative humidity is said to be the ideal air condition for virtually all air conditioned spaces, including houses.

Home cooling systems should have enough capacity to provide this much cooling and dehumidifying at all times. This means that a larger cooling unit is needed for a house in Phoenix, where summer temperatures often climb to 105°, than is needed for an identical house in Chicago

The other viable option is to set thermostats into certain rooms to shut registers and by the use of simple switches to move the controlling thermostat from one place to anotehr in effect. Actually, what you have is three or four installed thermostats at a switching mechanisms tells the furnace which ones it is to sense. This is an electronic problem which may be solved by the homeowner, but if the homeowner does not have expertise in this area, he should approach someone who works on these types of situations.

Another option for thermostat control is to adjust thermostats so that the temperature swings between the time the thermostat shuts off and comes back on is increased to 3-4°. This is very important in spring and fall and will lengthen the duty cycles and thus also the time between duty cycles.

where outside temperatures seldom exceed 95°. It also means that more capacity is needed in a humid area like New Orleans than in a drier area like Chicago having the same dry-bulb temperature.

The fact that we require 75° and a 50% relative humidity for bodily comfort in summer is based on staying in an air conditioned space for one or two hours or more. The same condition may feel overly cool when first entering an air conditioned store or restaurant. The longer one stays, however, the more our bodies adjust.

Therefore, it is a mistake to settle for a small air conditioner that can lower the indoor temperature to 80° only, or reduce indoor heat by only 12° to 15° below the outdoor temperature.

Each geographical location has a design temperature for cooling. This is not the highest temperature recorded...it is the recommended high (dry-bulb) temperature on which to base practical cooling requirements. Find the design ("Summer DB") temperature for your area at Figure 3.2. The same chart also lists wet-bulb ("Summer WB") temperatures...which indicate the prevailing humidity conditions. In any area where the WB temperature does not exceed 75°, do not worry about the humidity; but if it does exceed 75°, increase the cooling unit capacity for proper humidity control.

A worksheet is shown as Figure 3.3. You will need the same "tools" as for calculating heat requirements.

There is only one ceiling, the one at the top of the space to be cooled. In the case of a whole

FIGURE 3.3

AIR CONDITIONING - ESTIMATE WORK SHEET

TYPE OF HOUSE _____ Story. Attic Insulated? _____ in.
SIZE OF HOUSE _____ X _____ Walls Insulated? _____ in.
WINDOWS SHADED? Awnings ☐ Venetian Blinds ☐ No ☐

DESIGN TEMPERATURES: DRY BULB _____ °F; INSIDE _____ °F; DIFFERENCE _____ °F; *WET BULB _____ °F

COOLING FACTORS

		ATTIC VENT. FAN	NATURAL VENTILATION DARK ROOF	NATURAL VENTILATION LIGHT ROOF
CEILINGS WITH ATTIC SPACE	NO INSULATION	9	13	10
	2" INSULATION	3	6	5
	4" INSULATION	2	3	3
BUILT UP ROOF NO ATTIC SPACE	NO INSULATION		23	18
	2" ROOF INSULATION		11	9
	3" ROOF INSULATION		8	7
CEILING UNDER WARM ROOM, NO INSULATION			4	
EXPOSED WALLS: FRAME OR BRICK VENEER OR STUCCO	NO INSULATION		8	
	1" INSULATION OR ONE REFLECTIVE AIR SPACE		6	
	2" INSULATION OR TWO REFLECTIVE AIR SPACES		4	
	3½" INSULATION OR THREE REFLECTIVE AIR SPACES		3	
8" BRICK OR BLOCK	PLAIN OR PLASTERED DIRECT		10	
	FURRED, LATH & PLASTER, NO INSULATION		6	
	FURRED, 1" INSULATION OR ONE REFLECTIVE AIR SPACE		4	
	FURRED 2" INSULATION OR TWO REFLECTIVE AIR SPACES		3	
	FURRED, 3½" INSULATION OR THREE REFLECTIVE AIR SPACES		2	
12" ADOBE WALL			5	
FLOORS: OVER WARM ROOM			5	
OVER BASEMENT OR SLAB FLOOR OR CLOSED CRAWL SPACE			0	
OVER OPEN CRAWL SPACE			7	

NOTE MOST OF THE ABOVE FACTORS WERE DERIVED FROM MANUAL J PUBLISHED BY THE NATIONAL WARM AIR HEATING & AIR CONDITIONING ASS'N

SELECT FROM THESE FACTORS IN ESTIMATING COOLING LOAD AT RIGHT.

COOLING ESTIMATE

TYPE OF EXPOSURE	COOLING FACTORS	X AREA =	B.T.U./hr.
PEOPLE – FIGURE 2 PEOPLE PER BEDROOM	400	X Number =	
CEILING		X Lgth X Width =	
EXPOSED WALLS GROSS AREA		X Perim X Ceil. Ht =	
PARTITION – NEXT TO WARM ROOM GROSS AREA	6.5	X Lgth X Ceil. Ht =	
FLOOR (ONLY OVER WARM AREA)		X Lgth X Width =	
KITCHEN – INCLUDE IN TOTAL			1,500
GLASS – WINDOWS AND DOORS		No. Windows X 15 or Area	
NORTH, OR COMPLETE SHADE	40	X =	
SOUTH, UNSHADED	65	X =	
SOUTH, VEN. BLINDS OR DRAPES	45	X =	
EAST AND WEST UNSHADED	117	X =	
EAST AND WEST VEN. BLINDS OR DRAPES	80	X =	
WOOD DOORS	16	X No. Doors X 20 =	
TOTAL – Based on 20° Temperature Difference (Total Includes Moisture Removal Load)			
YOUR DESIGN TEMPERATURE CORRECTION FOR			X _____
15° = .75 | 25° = 1.25 | 30° = 1.50 | 35° = 1.75			
* CORRECTION FOR HIGH HUMIDITY AREAS: If Wet Bulb Temp. is 78° Add 5%; If Wet Bulb Temp. is 80° Add 10%			
TOTAL			

house, this ceiling may be one with an attic above it...or one without an attic. In the case of a first-floor apartment, there is no ceiling if the floor above is cooled...but you do count the ceiling if the floor above is not cooled and there is no insulation between. This same rule applied to the floor of a second-floor apartment; but in the case of a whole house the floor is counted only when there is an open crawl space (does not count if it is over a basement, enclosed crawl space or on a slab).

The gross area of exposed walls is the house perimeter times the above-ground wall height. Windows and doors are simply counted (as for heating calculation)...except that you will count those on each side of the house (north, south, etc.) separately, and must also consider whether or not each window is normally shaded (by blinds, drawn draperies, etc.). People (house occupants, at 2 per bedroom) must also be counted, as shown on the worksheet.

Multiply each of the above by the proper "COOLING FACTOR" listed on the form. Add these together with the 1500 (BTU's) listed for your kitchen to arrive at a total (you can scratch this off if kitchen is entirely separate from area to be cooled). If your DV temperature does not exceed 75°, this total is the cooling unit capacity (in BTU's) needed to maintain a 75° inside temperature. However, if your DB temperature exceeds 95°, or if you want a lower than 75° inside temperature, first figure the difference between your DB temperature and the desired inside temperature then substract 20 from this to learn how many more degrees of cooling you will need. Now add to

the above total the amount indicated under "YOUR DESIGN TEMPERATURE CORRECTION FOR" on the work sheet (for instance, if you need 15° more cooling, you must add on 3/4 of above total; for 25° more, add on 1-1/4, etc.) Finally, if your WB temperature exceeds 75°, you must add on still more (5% of the first total if it is 78°; 10% if it is 80°) to maintain an inside 50% relative humidity.

Figures 3.4 and 3.5 illustrate how to use the worksheet for estimating costing requirements for a sample house. Study the example before preparing your worksheet.

FIGURE 3.4

AIR CONDITIONING - ESTIMATE WORK SHEET

TYPE OF HOUSE Two Story. Attic Insulated? 3 5/8 in.
SIZE OF HOUSE 25' x 28' Walls Insulated? 2 in.
WINDOWS SHADED? Awnings X Venetian Blinds ☐ No ☐

DESIGN TEMPERATURES — DRY BULB 100 °F. INSIDE 75 °F. DIFFERENCE 25 °F. *WET BULB 78 °F

COOLING FACTORS

		ATTIC VENT. FAN	NATURAL VENTILATION DARK ROOF	NATURAL VENTILATION LIGHT ROOF
WITH ATTIC SPACE	NO INSULATION	9	13	10
	2" INSULATION	3	6	5
	4" INSULATION	2	(3)	3
BUILT UP ROOF NO ATTIC SPACE	NO INSULATION		23	18
	2" ROOF INSULATION		11	9
	3" ROOF INSULATION		8	7
CEILING UNDER WARM ROOM, NO INSULATION			4	
FRAME OR BRICK VENEER OR STUCCO	NO INSULATION		8	
	1" INSULATION OR ONE REFLECTIVE AIR SPACE		6	
	2" INSULATION OR TWO REFLECTIVE AIR SPACES		(4)	
	3½" INSULATION OR THREE REFLECTIVE AIR SPACES		3	
8" BRICK OR BLOCK	PLAIN OR PLASTERED DIRECT		10	
	FURRED, LATH & PLASTER, NO INSULATION		6	
	FURRED, 1" INSULATION OR ONE REFLECTIVE AIR SPACE		4	
	FURRED 2" INSULATION OR TWO REFLECTIVE AIR SPACES		3	
	FURRED, 3½" INSULATION OR THREE REFLECTIVE AIR SPACES		2	
12" ADOBE WALL			5	
FLOOR OVER WARM ROOM			5	
OVER BASEMENT OR SLAB FLOOR OR CLOSED CRAWL SPACE			0	
OVER OPEN CRAWL SPACE			7	

NOTE MOST OF THE ABOVE FACTORS WERE DERIVED FROM MANUAL J PUBLISHED BY THE NATIONAL WARM AIR HEATING & AIR CONDITIONING ASS'N

SELECT FROM THESE FACTORS IN ESTIMATING COOLING LOAD AT RIGHT

COOLING ESTIMATE

TYPE OF EXPOSURE	COOLING FACTORS	X	AREA	=	B.T.U./hr
PEOPLE – FIGURE 2 PEOPLE PER BEDROOM	400	X	Number 5	=	2000
CEILING	3	X	Lgth X Width 28 x 25	=	2100
EXPOSED WALLS — GROSS AREA	4	X	Perim. X Ceil. Ht. 106 x 16	=	6784
PARTITION — NEXT TO WARM ROOM — GROSS AREA	6.5	X	Lgth. X Ceil. Ht.	=	
FLOOR (ONLY OVER WARM AREA)		X	Lgth. X Width	=	
KITCHEN – INCLUDE IN TOTAL →					1,500
GLASS – WINDOWS AND DOORS			No. Windows X 15 or Area		
NORTH, OR COMPLETE SHADE	40	X	17 x 15	=	10200
SOUTH, UNSHADED	65	X		=	
SOUTH, VEN. BLINDS OR DRAPES	45	X		=	
EAST AND WEST UNSHADED	117	X		=	
EAST AND WEST VEN. BLINDS OR DRAPES	80	X			
WOOD DOORS	16	X	No. Doors X 20 2 x 20	=	640
TOTAL – Based on 20° Temperature Difference (Total Includes Moisture Removal Load)					23224
YOUR DESIGN TEMPERATURE CORRECTION FOR 15° = .75 | 25° = 1.25 | 30° = 1.50 | 35° = 1.75				X	1.25
					29030
* CORRECTION FOR HIGH HUMIDITY AREAS — If Wet Bulb Temp. is 78° Add 5% — If Wet Bulb Temp. is 80° Add 10%					1451
TOTAL →					30481

DETERMINING THE COOLING FOR A SAMPLE HOUSE

Enter your information and calculations on the Work Sheet as shown following:

PEOPLE This 3-bedroom home will normally house 5 people, which multiplied by the factor "400", gives a cooling load of 5 x 400 or 2000 BTU/Hr.

CEILING The area is length of house times width (28 x 25) or 700 sq. ft. The ceiling cooling factor, for a dark color roof and attic space with between 2-in. and 4-in. insulation, is "3". The load then is 700 x 3 or 2100 BTU/Hr.

FIGURE 3.5

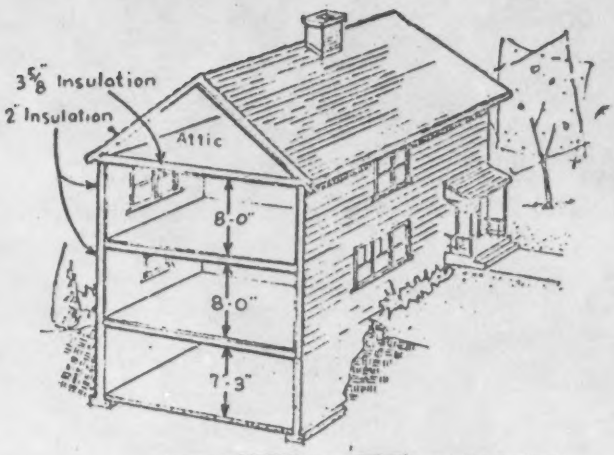
HOUSE SPECIFICATIONS

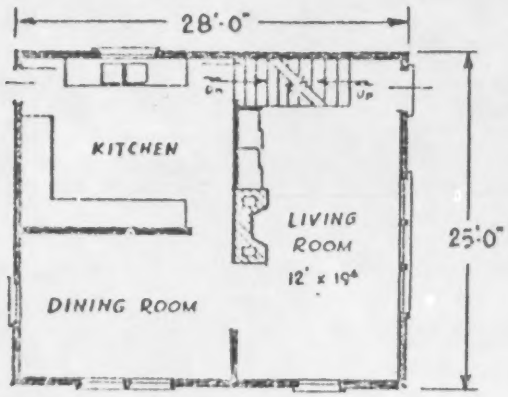
DESIGN TEMPERATURES

100° Dry Bulb – 75° Inside = 25° Difference

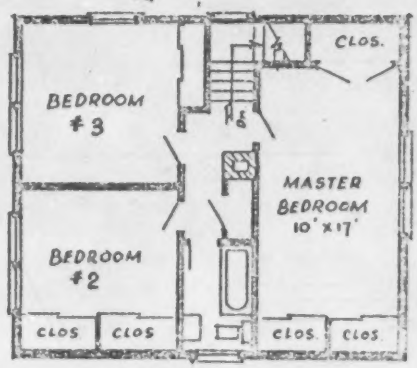
78° Wet Bulb Temp.

Roof	Dark Color
Walls	Frame With 2" Insulation
Ceiling	With Attic and 3 5/8" Insulation
Windows	All North or With Awnings
Basement	Under Entire House





FIRST FLOOR



SECOND FLOOR

EXPOSED WALLS Total area of exposed walls is perimeter of house times ceiling height (of upper ceiling). This is 105 (25+28+25+28) times 16 (2 stories) or 1,696 sq. ft. The cooling factor table shows frame walls with 2-in. insulation has the factor "4". Multiplying 1,696 sq. ft. by 4 gives a load of 6,784 BTU/Hr.

FLOOR Over basement . . . no factor required.

WINDOWS House has 17 windows, either facing north or completely shaded by awnings. This means that all windows will have a cooling factor of "40". First, multiply the 17 windows by "15" for glass area (17 x 15 = 255), then by 40 (255 x 40 = 10,200). This means that the cooling load for glass is 10,200 BTU/Hr.

WOOD DOORS The 2 wood doors to the outside are multiplied by "20" for area (2 x 20 = 40), then by the indicated factor "16" (40 x 16 = 640) for a load of 640 BTU/Hr.

KITCHEN A standard load of 1,500 BTU/Hr. is added for kitchen activities.

TOTAL COOLING LOAD (based on 20° temperature difference) This is the total of the preceding individual loads. In this example, it is 2,000 + 2,100 + 6,784 + 10,200 + 640 + 1,500 or 23,224 BTU/Hr.

DESIGN TEMPERATURE CORRECTION An allowance must be made because the difference between the outside dry bulb temperature (100°) and the desired inside temperature (75°) is greater than 20°. The Work Sheet indicates that a difference of 25° (100° – 75°) requires a correction factor of 1.25. The adjusted cooling load (23,224 x 1.25) then becomes 29,030 BTU/Hr.

HIGH HUMIDITY CORRECTION This area has a wet bulb reading of 78°. The Work Sheet indicates that under such conditions, 5% must be added to the cooling load (29,030 x .05 = 1451; 29,030 + 1451 = 30,481). The final cooling load then becomes 30,481 BTU/Hr.

D. MAINTENANCE AND USE

The efficiency with which an air conditioner can dehumidify the air depends primarily upon how cold the evaporator coil gets. If the fan of the air conditioner is set at a low speed, the coil will get colder and more moisture will be removed from the air; however, the air conditioner may not be able to cool the house enough on especially hot days. At high fan speeds, the air conditioner will be able to cool better, but it will not be able to dehumidify as well. For best comfort, it is humid days and a high fan setting on hot days.

Constantly adjusting the thermostat up and down does no good. An air conditioner will not cool a room any faster if the thermostat is set to a much cooler setting when it is first turned on. An air conditioner turns on when the thermostat senses that the room is too warm, and it does not turn off until the room is cool enough. The fastest way to cool a room is to set the fan speed on high. This will make the air conditioner work at maximum capacity. Set the thermostat at a comfortable temperature, then leave it alone, except for minor changes to take care of cool or hot days. In general, an air conditioner with several fan speeds will permit the room to be kept at a more uniform temperature without having to adjust the thermostat as much.

Should one open up the house during the day when not at home? This is not a good idea if one lives in a climate with humid summers. If one closes up the house during the day, the temperature inside may increase, but the humidity will not-it will decrease. The temperature inside a

sealed home will not become much hotter than it gets outside. This will permit the air conditioner to cool your home faster, and it will save electricity as well. As a general rule, if the humidity of the outside air is more than 30% it will be more economical to close up the house when leaving in the morning. The temperature inside their house may get as hot as the outdoors, but the lower humidity inside makes the home feel much cooler.

There are many things one can do to keep the air conditioning operating at peak efficiency. An air conditioner has filters that get clogged with dust, finned coils that become dirty, and motors that need lubricating. These simple tasks are not difficult to do and require only a wrench and a couple of screwdrivers.

All air conditioners should be lubricated and cleaned each year. The best time for doing this is a month or so before the summer cooling season begins.

As room air is drawn into the air conditioner it first passes through a foam or aluminum mesh filter much like the air filters in many furnaces. The air filters are cleanable, and they should be cleaned several times a year.

The evaporator coil at the front of the air conditioner rarely needs attention; the cleaning action of water condensing on it usually does a good job of keeping it free of dirt. However, one should routinely inspect this coil whenever he/she cleans the air filter. If the air filter has moved or allowed much dirt to pass through, sections of the evaporator coil may require some cleaning. After several years of use, some sections of the coil are bound to accumulate dirt.

If the thermostat on an air conditioner is set at a very low temperature, the evaporator coil may begin to ice up. What happens is that the temperature of the evaporator drops below the freezing point and ice begins to form on the evaporator. Ice usually starts to form along the refrigerant inlet at the top of the coil, and it gradually progresses downward until the whole coil is blocked with ice. Since the formation of ice restricts the flow of air through the evaporator coil, the more ice that forms, the colder the coil will get, and this causes even more ice to form.

The common reason for the evaporator icing up is setting the thermostat at too low a temperature. When the thermostat is set properly, the room will stay at a fairly comfortable and uniform temperature.

The moisture that collects on the evaporator drains back to a pan under the condenser coil. There, a ring on the fan blade often picks up the water and slings it onto the condenser. This technique increases the efficiency of the air conditioner because the evaporating water helps cool the condenser coil.

The condenser gets much dirtier than the evaporator. At most, a wire screen is used to keep out leaves and other large objects, but this still lets plenty of dirt and trash through to the condenser. To do a good cleaning job, the case should be removed from the air conditioner to get at all the parts inside.

Air conditioners normally have two motors, one for the fan and the other for the compressor. In this way, the fan motor can be running all the time to circulate air in the room, while the compressor motor need only run when

the thermostat calls for more cooling. The fan motor may be single-shafted or double-shafted, depending on how the fan blades are connected to the motor. The most usual arrangement is the double-shafted motor, in which the shaft extends from each end of the motor. A large fan blade is connected to one shaft of the motor to circulate air over the outside condenser coil. The other end of the shaft extends through a panel to a squirrel cage fan that circulates air over the evaporator coil and into the room. The advantage to using a squirrel cage fan on the inside is that it is much quieter in operation.

During the yearly tuneup, clean the fan motor and fan blades (particularly the condenser fan blades). The fan motor should be oiled too, though some of the newer fans have sealed bearings that do not require oiling every year.

Once a year, clean out the parts of a central air conditioner, the same as for a room air conditioner. The air filter should be cleaned or replaced about once a month. When the evaporator coil is located in the coil case of your furnace, the central air conditioner uses the furnace fan, so this fan will require more frequent inspection and cleaning. With the alternate, single-unit system, the central air conditioner contains a separate fan to force cool air into the furnace duct system. Electrically heated homes may use this alternate system with duct work just for air conditioning.

Grass, leaves, and dirt may collect in the condensing unit located outside the house. Clean out the unit to remove any restrictions that could reduce the efficiency of the unit or impair its operation.

E. DEHUMIDIFY IN SUMMER

Summer discomfort is largely caused by high humidity. The air's excess water content prevents sweat from evaporating and thus diminishes the body's natural cooling effect.

Removing excess water from the air in homes is possible without resorting to the expense of air conditioning. A dehumidifier is and apparatus that draws room air over a cooling coil where it loses moisture. Water is removed by condensation on cold coils. It is then heated slightly and returned by fan.

When buying a unit, look for the water removal capacity rating of the Association of Home Appliances Manufacturers. Humidifiers can range in price from $90 (with a water removal capacity of eleven pints a day) to $150 (with a 30 pint capacity and convenience features). The electrical operating rate can change from $.20 to $.50 per day. Operating costs are reduced when an area has been sufficiently dried and the machine does not have to run steadily.

For Safe, Efficient Operation

- -Read the owner's manual.
- -Place the unit at least 6 inches (15cm) from the nearest wall for free air flow.
- -Shut all doors and windows in the area to be dried.
- -For the first few days, turn the humidistat to "Drier" or "Extra Dry."
- -Turn the machine off and disconnect power cord before emptying the water pans; be sure the area and unit are dry before reconnecting the cord.
- -On cool days, check the cold coils for frosting; turn off until melted.

-Always unplug the cord before cleaning the unit; dust the grills and wipe the cabinet.

-Every few weeks, clean the inside of the water container with a soft cloth and a mild detergent to prevent mold, mildew, and bacteria.

-Once a month, dust the lint from the cold coils.

F. TIPS FOR COOLING ENERGY SAVERS

The following tips for cooling energy savers are from the U.S. Department of Energy and serve as a convenient summary for the points discussed in this unit.

-Overcooling is expensive and wastes energy. Don't use or buy more cooling equipment capacity than you actually need.

-If you need central air-conditioning, select the smallest and least powerful system that will cool your home adequately. A larger unit than you need only costs more to run but probably won't remove enough mooisture from the air.

-Ask your dealer to help you determine how much cooling power you need for the space you have to cool and for the climate in which you live. (For further information, see page 19, Energy Efficiency Ratios.)

-Make sure the ducts in your air-conditioning system are properly insulated, especially those that pass through the attic or other uncooled spaces. This could save you almost 9 percent in cooling costs.

-If you don't need central air-conditioning, consider using individual window or through-the-wall units in rooms that need cooling from time to time. Select the smallest and least powerful units for the rooms you need to cool. As a rule, these will cost less to buy and less to operate.

-Install a whole-house ventilating fan in your attic or in an upstairs window to cool the house when it's cool outside, even if you have central air-conditioning.

-It will pay to see the fan rather than air-conditioning when the outside temperature is below 82 degrees. When windows in the house are open, the fan pulls cool air through the house and exhausts warm air through the attic.

When you use air conditioning...

-Set your thermostat at 78 degrees, a reasonably comfortable and energy-efficient indoor temperature.

-The higher the setting and the less difference between indoor and outdoor temperature, the less outdoor hot air will flow into the building.

-If the 78°F setting raises your home temperature 6 degrees (from 72°F to 78°F, for example), you should save between 12 and 47 percent in cooling costs, depending on where you live.

-Don't set your thermostat at a colder setting than normal when you turn your air--conditioner on. It will NOT cool faster, it WILL cool to a lower temperature than you need and use more energy.

-Set the fan speed on high except in very humid weather. When it's humid, set the fan speed at low; you'll get less cooling but more moisture will be removed from the air.

-Clean or replace air-conditioning filters at least once a month. When the filter is dirty, the fan has to run longer to move the same amount of air and this takes more electricity.

-Turn off your window air-conditioners when you leave a room for several hours. You'll use less energy cooling the room down later than if you had left the unit running.

-Consider using a fan with your window air-conditioner to spread the cooled air farther without greatly increasing your power use. But be sure the air-conditioner is strong enough to help cool the additional space.

-Don't place lamps or TV sets near your air-conditioning thermostat. Heat from these appliances is sensed by the thermostat and could cause the air-conditioner to run longer than necessary.

With or without air condi tioning...

-Keep out daytime sun with vertical louvers or awnings on the outside of your windows, or draw draperies, blinds, and shades indoors. You can reduce heat gain from the sun by as much as 80 percent this easy way.

-Keep lights low or off. Electric lights generate heat and add to the load on your air-conditioner.

-Do your cooking and use other heat-generating appliances in the early morning and late evening hours whenever possible.

-Open the windows instead of using your air-conditioner or electric fan on cooler days and during cooler hours.

-Turn off the furnace pilot light in summer, but be sure it's reignited before you turn the furnace on again.

-Dress for the warmer indoor temperatures. Neat but casual clothes of lightweight open-weave fabrics are most comfortable.

-A women will feel cooler in a lightweight skirt instead of slacks. A man will feel cooler in a short-sleeved shirt than in a long-sleeved shirt of the same weight fabric.

Without air-conditioning...

-Be sure to keep windows and outside doors closed during the hottest hours of the day.

-Use windows or whole-house ventilation fans to cool the house when it's cool outside.

-Use vents and exhaust fans to pull heat and moisture from the attic, kitchen and laundry directly to the outside.

If everyone raised air-conditioning temperature 6 degrees, we'd save the equivalent of 36 billion kilowatt-hours of electricity used in the nation in 1 year.

UNIT IV

DUCTING WORK

OBJECTIVE: Upon completion of this unit the student will be able to:

a. Calculate duct size needed for supply conditioned air to various rooms in a home.

b. Distinguish between types of ducts and duct material.

c. Discuss the operating specifications of ducts and registers.

d. Discuss various duct piping arrangements for certain types of building constructions:

1. Extended Plenum System
2. Radial Piping System

e. Recognize the importance of duct insulation.

LECTURE

LABORATORY

INTRODUCTION:

In a central heating or central cooling system, the delivery system for the conditioned air is through duct work.

The specific type of duct system used depends upon the type of structure, the equipment location and the layout of the building. Ideally, the furnace should be located near the center of the house. This will eliminate long runs of ducts, which is more important since conditioned air passing through long ducts will lose or gain considerable heat before reaching its distination. Also, long ducts increase the

incidence of friction between the air and the sides of the ducts which causes more energy loss.

Single-story houses may have the ductwork terminating in registers delivering air from either the floor, walls or the ceiling. However, it is recommended that overhead distribution be used only in mild winter climates unless some provision is made to heat the floors in a cold climate.

A. CALCULATION OF DUCT SIZE

Duct sizes are determined according to airflow rates in CFM (cubic feet per minute). Size is determined by the amount of air that is required to either heat or cool a room. The general formula is $S/sf = \frac{V}{AF}$ where S is the size in square feet, V is the volume of air required and A/F is the air flow in feet per minute (usually 600 fpm in the average room). V is determined by several factors including heat loss temperature of the air coming off the furnace or air conditioner and the overall volume of the room. Generally speaking, air conditioning ducts must be larger than heating ducts. Ducts are commonly rectangular or circular in cross section, and are usually designed for velocities of 150 to 1500 feet per minute (fpm).

Cost of duct work varies. As a rule of thumb, at present prices, ductwork is estimated at $75-$100 per room register.

B. TYPES OF DUCTS

Ducts are usually made of:

Galvanized steel sheet
Black-iron sheet
Stainless-steel sheet
Aluminum sheet
Fibrous glass sheet

Heating ducts are usually 6" in diameter and cooling ducts 8".

The common functions of ducts and their operating specifications are:

Air intake from outside	500-1200 CFM
Air washers (dust removers)	500- 600 "
Branch ducts and risers	500-1800 "
Exhaust risers	500-1800 "
Heater corrections	700-1400 "
Humidifiers	500- 600 "
Main Exhaust ducts	900-1500 "
Main Ventilating ducts	500-1500 "
Supply grilles near floor	150- 250 "
Supply openings	350- 500 "
Supply registers and grilles	250- 450 "

C. DUCT SYSTEM DESIGNS

There are several techniques to consider in designing a good energy saving duct system. Sharp turns should be eliminated when possible in order to cut down on pressure losses that will occur when fast moving air is forced to turn a corner. Turning vanes should be installed inside elbows where sharp turns are necessary.

Ducts should be properly sized for the blower. If undersized, the air will move too fast through the ducts causing unwanted noise and excessive losses due to air friction along the duct walls. Long runs of ducts should be eliminated also to avoid friction losses.

Location of the vents is also important. In a home where heating is the most

important consideration due to long cold winters, warm air should enter the room near the floor so that the heat will rise by convection. The return air vents should be placed high on the walls and on opposite sides of the room. This allows the incoming warm air to rise from the floor and travel across the room.

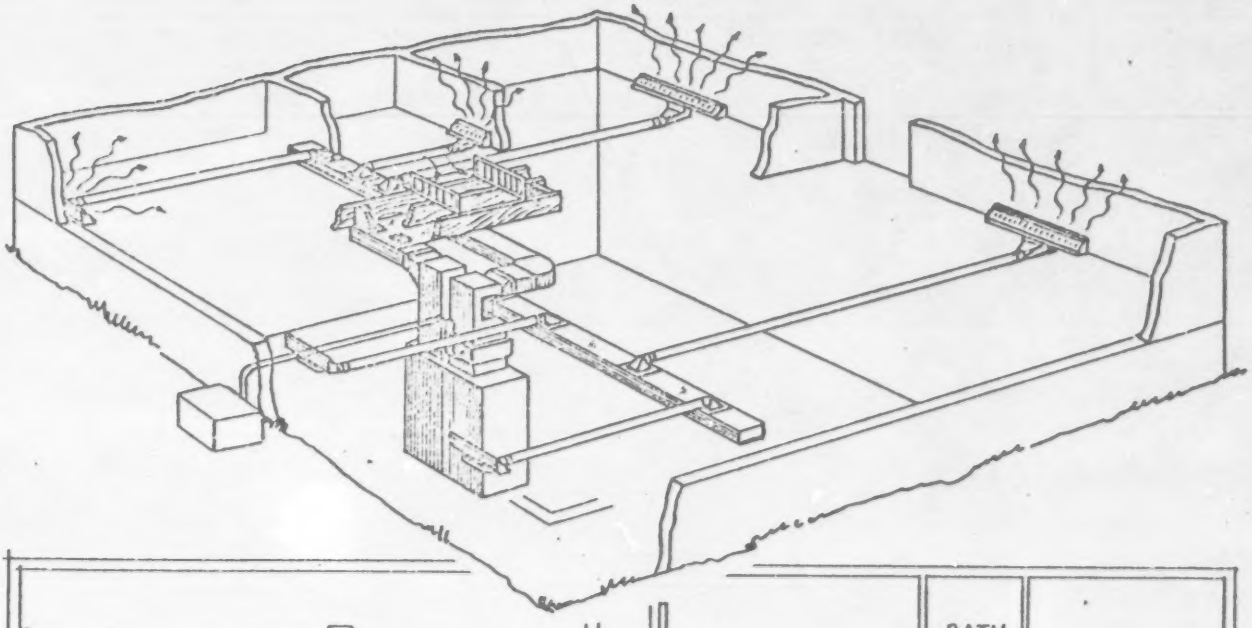
Zoning of heating and cooling systems almost always provides the opportunity for lower energy consumption, since each zone can be maintained at the temperature required, without regard to the temperatures in other zones. Zoning also provides the owner with the opportunity to cut back on the heating and/or cooling to any rooms not being used. Tests have shown that zoning can achieve energy savings of 20% and more.

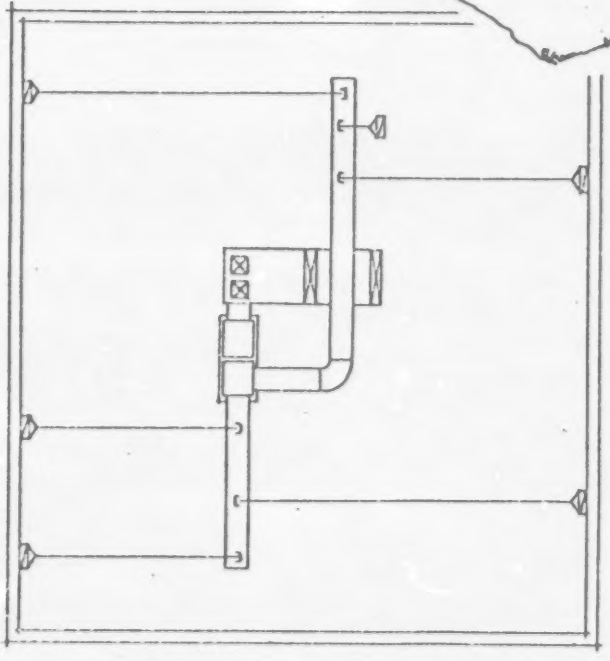
Figures 4.1 - 4.11 show various duct piping arrangements for certain types of building constructions.

ONE-STORY HOUSE
WITH BASEMENT
Figure 4.1

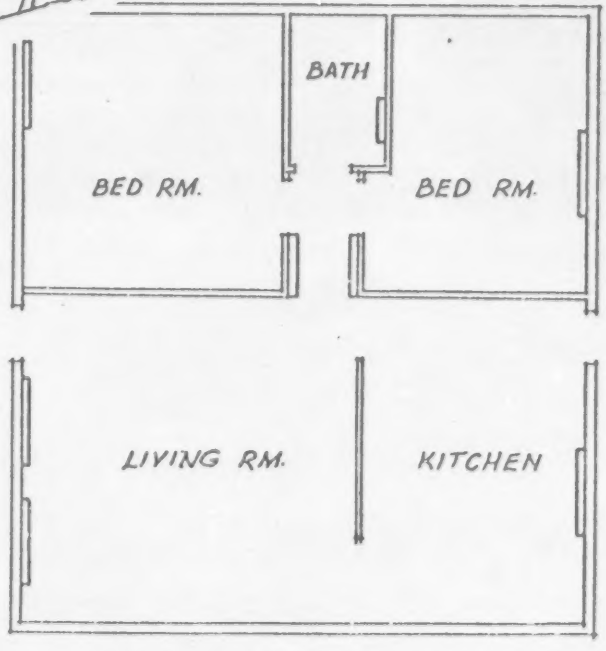
EXTENDED PLENUM SYSTEM

The extended plenum system usually is preferred for basement installation because of its neat appearance. Branch pipes to outlets may be round or rectangular and are run between or beneath basement joists. The extended plenum is usually required for larger installations.





BASEMENT PIPING PLAN

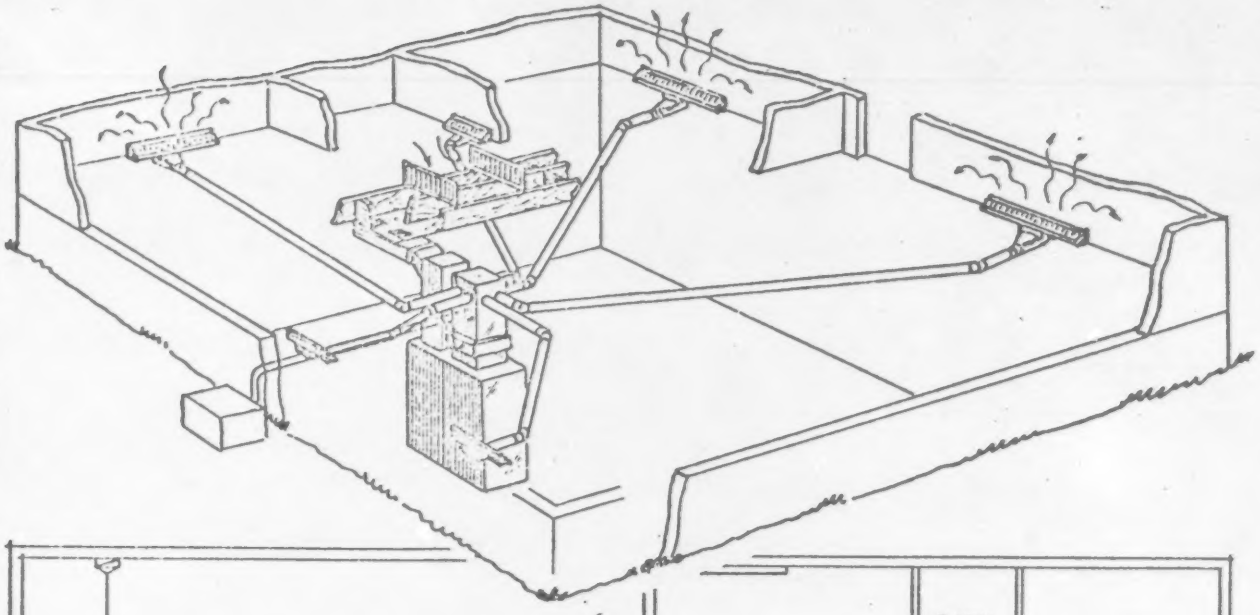


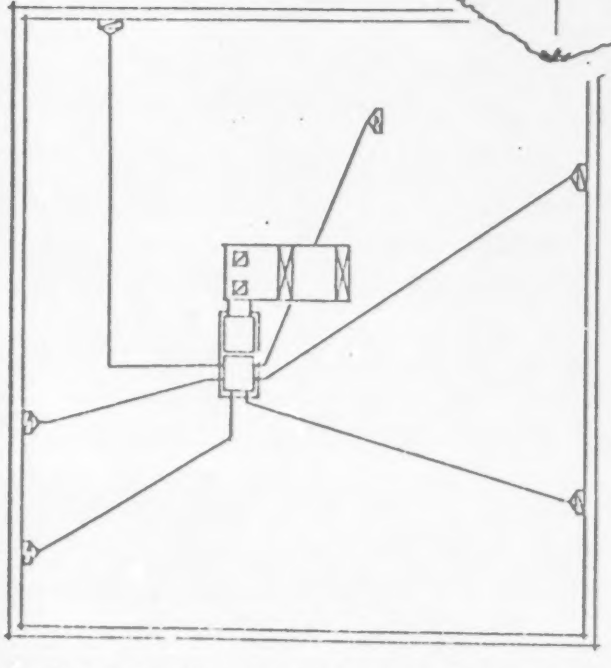
FIRST FLOOR PLAN

Figure 4.2

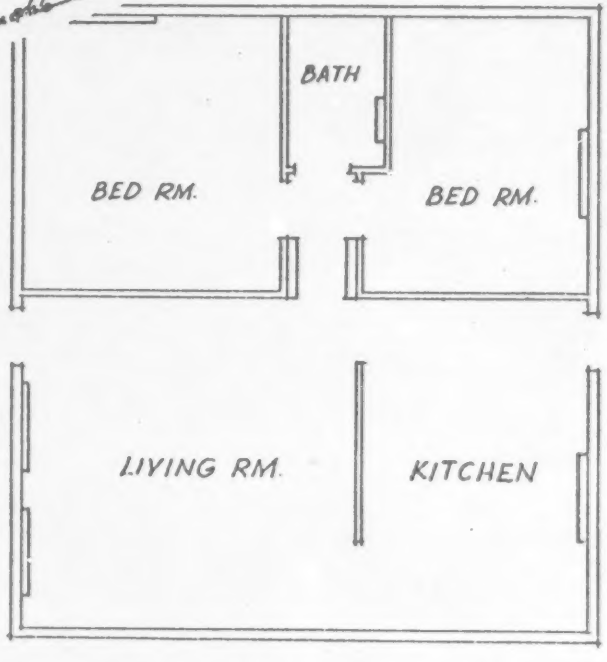
RADIAL PIPING SYSTEM

This method of piping can be used where length of individual pipe runs does not exceed limits of pipe capacity and where appearance is not a factor. Pipes are suspended from basement joists and run in as direct a line as possible from plenum to outlet connection. Requires a minimum amount of pipe.





BASEMENT PIPING PLAN

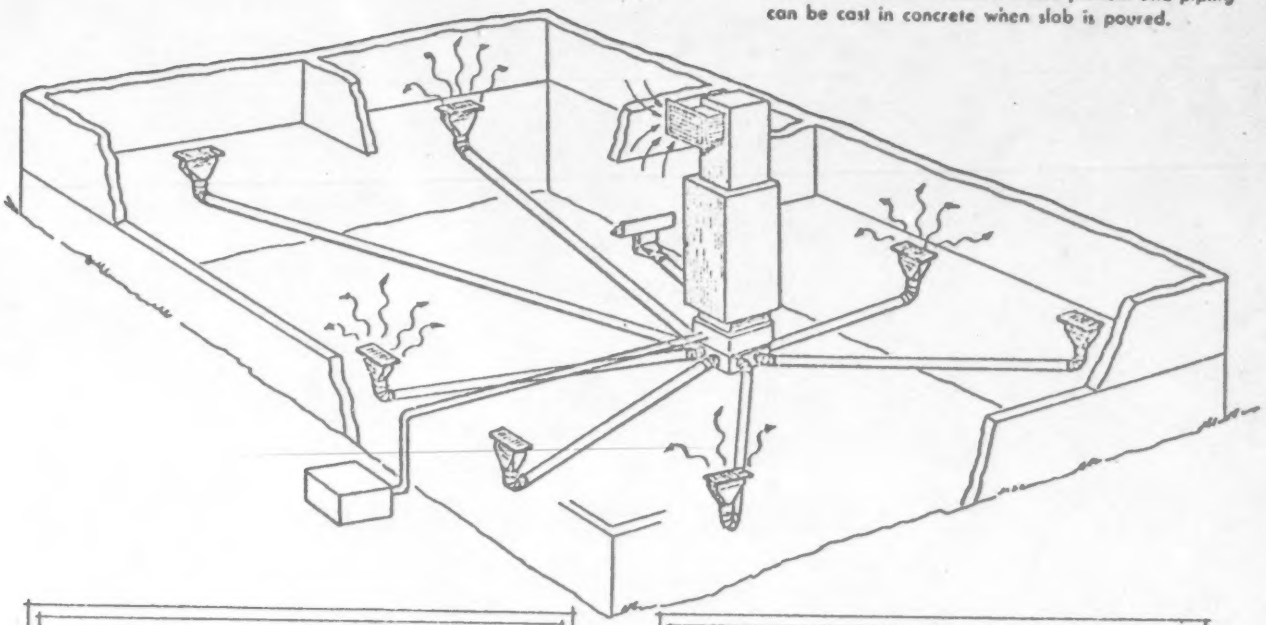


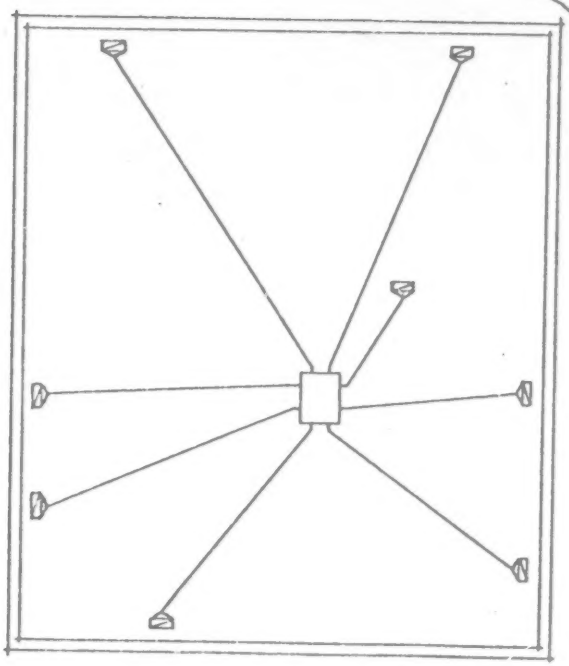
FIRST FLOOR PLAN

ONE-STORY HOUSE
WITH CRAWL SPACE
Figure 4.3

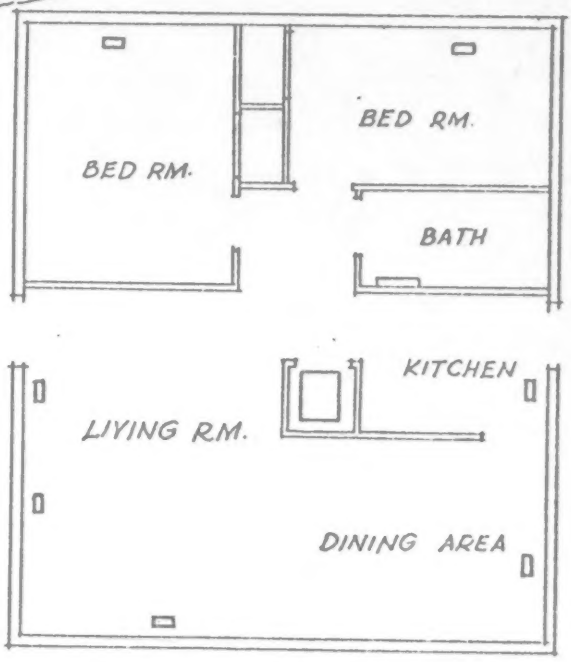
RADIAL PIPING SYSTEM, COUNTERFLOW FURNACE

This combination is widely used in compact, one-story houses with crawl space. Warm air plenum under furnace extends into crawl space, where pipes to supply outlets are run beneath joists. Supply pipes and plenum should be insulated. Similar system is used with slab construction where plenum and piping can be cast in concrete when slab is poured.





CRAWL SPACE PIPING PLAN



FIRST FLOOR PLAN

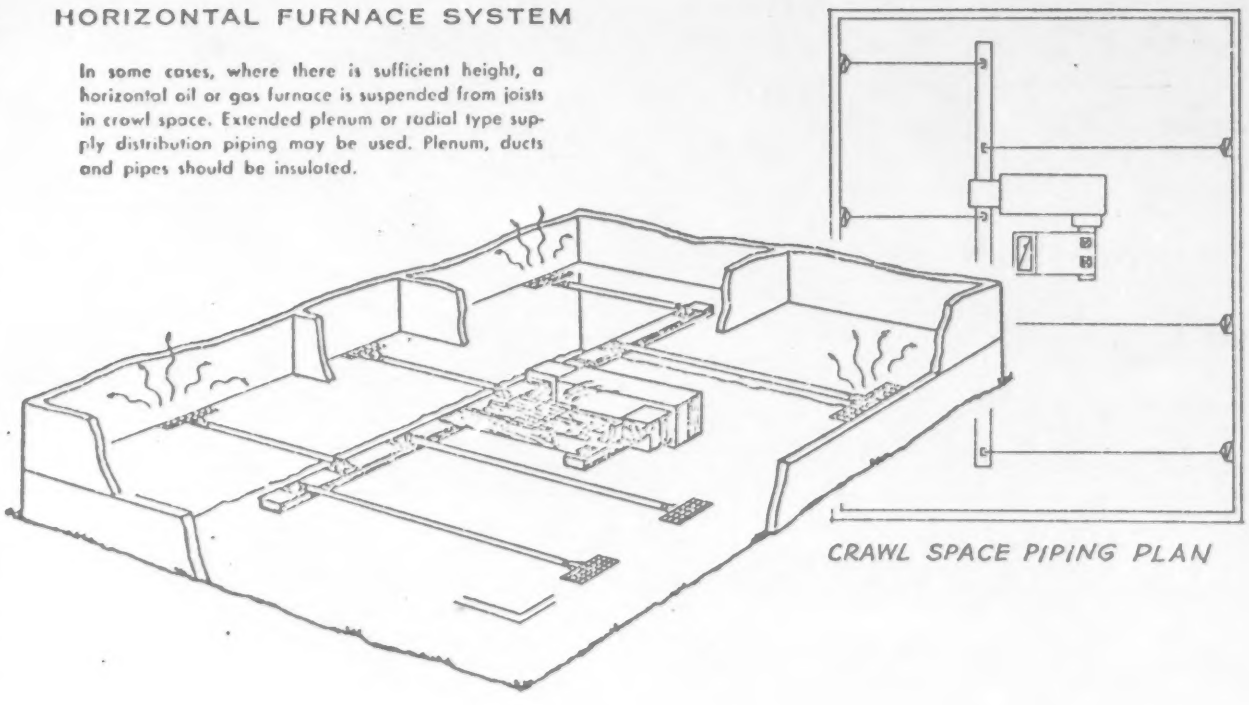
91

AIR SYSTEMS

Figure 4.4

HORIZONTAL FURNACE SYSTEM

In some cases, where there is sufficient height, a horizontal oil or gas furnace is suspended from joists in crawl space. Extended plenum or radial type supply distribution piping may be used. Plenum, ducts and pipes should be insulated.

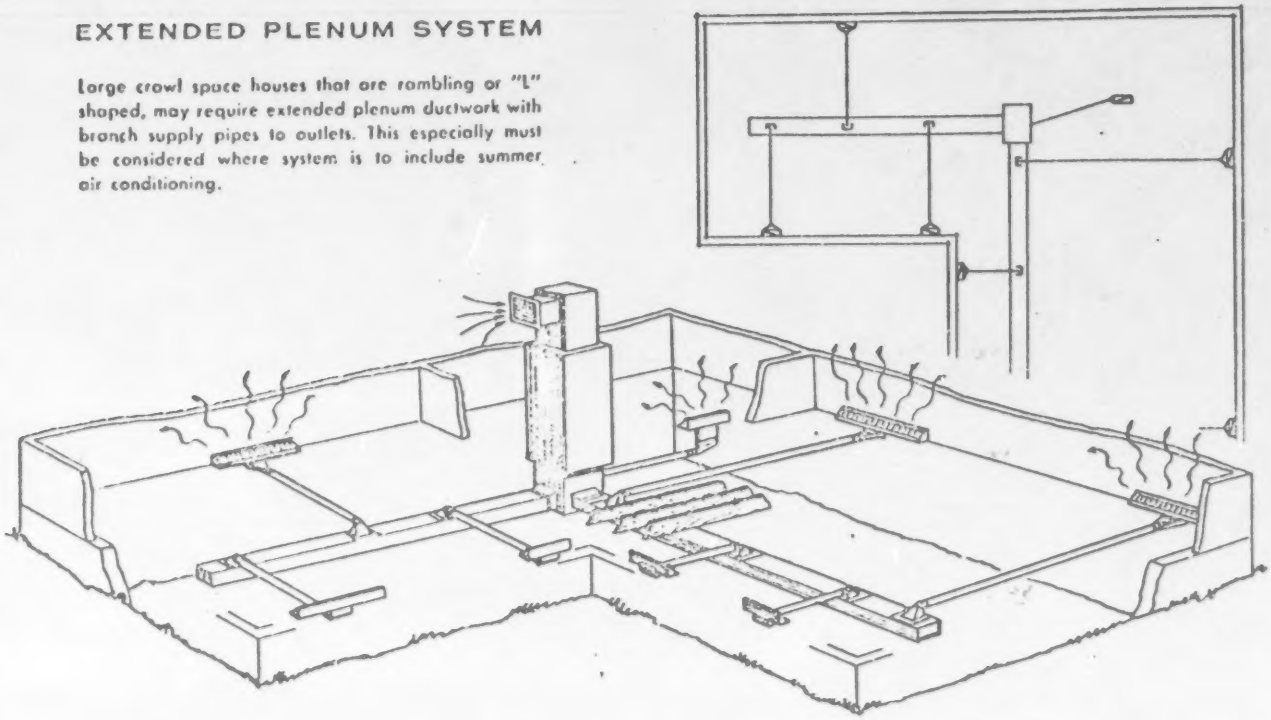


CRAWL SPACE PIPING PLAN

Figure 4.5

EXTENDED PLENUM SYSTEM

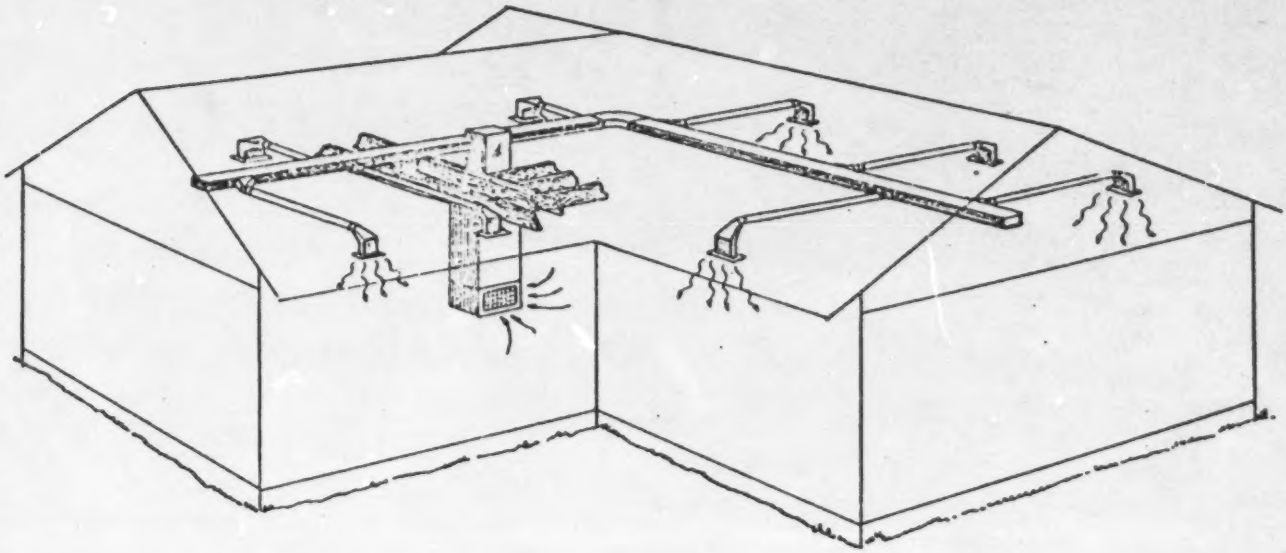
Large crawl space houses that are rambling or "L" shaped, may require extended plenum ductwork with branch supply pipes to outlets. This especially must be considered where system is to include summer air conditioning.

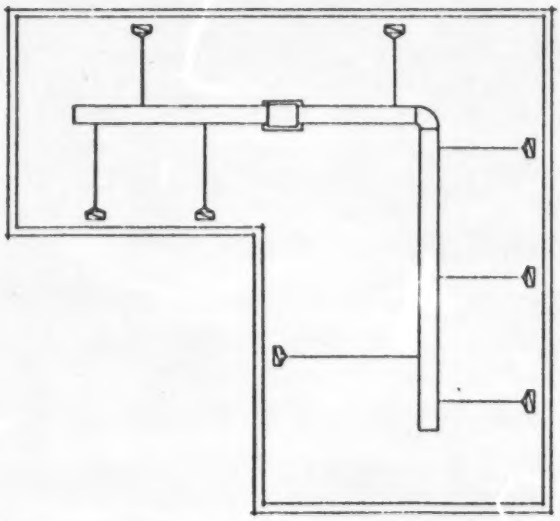


HOUSE ON CONCRETE SLAB
Figure 4.6

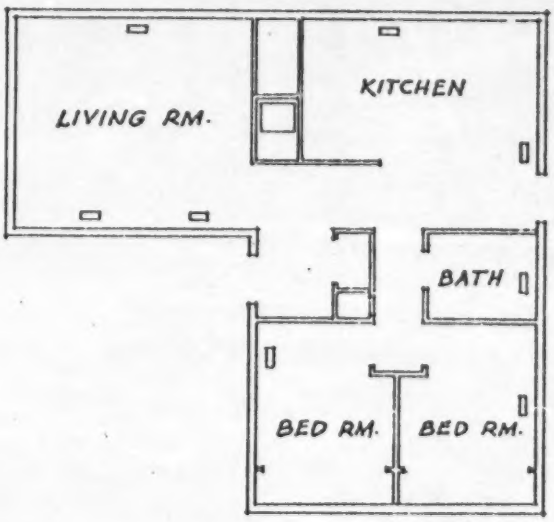
EXTENDED PLENUM IN ATTIC

Unless furnace plenum and supply pipes are cast in the concrete when slab is poured, piping for this type of house must run in the attic. Ducts and piping run across top of joists. Floor diffusers are turned upside down and installed in ceiling near outside walls. Round diffusers centered in room ceilings may be used. Plenum and piping must be insulated.





ATTIC PIPING PLAN

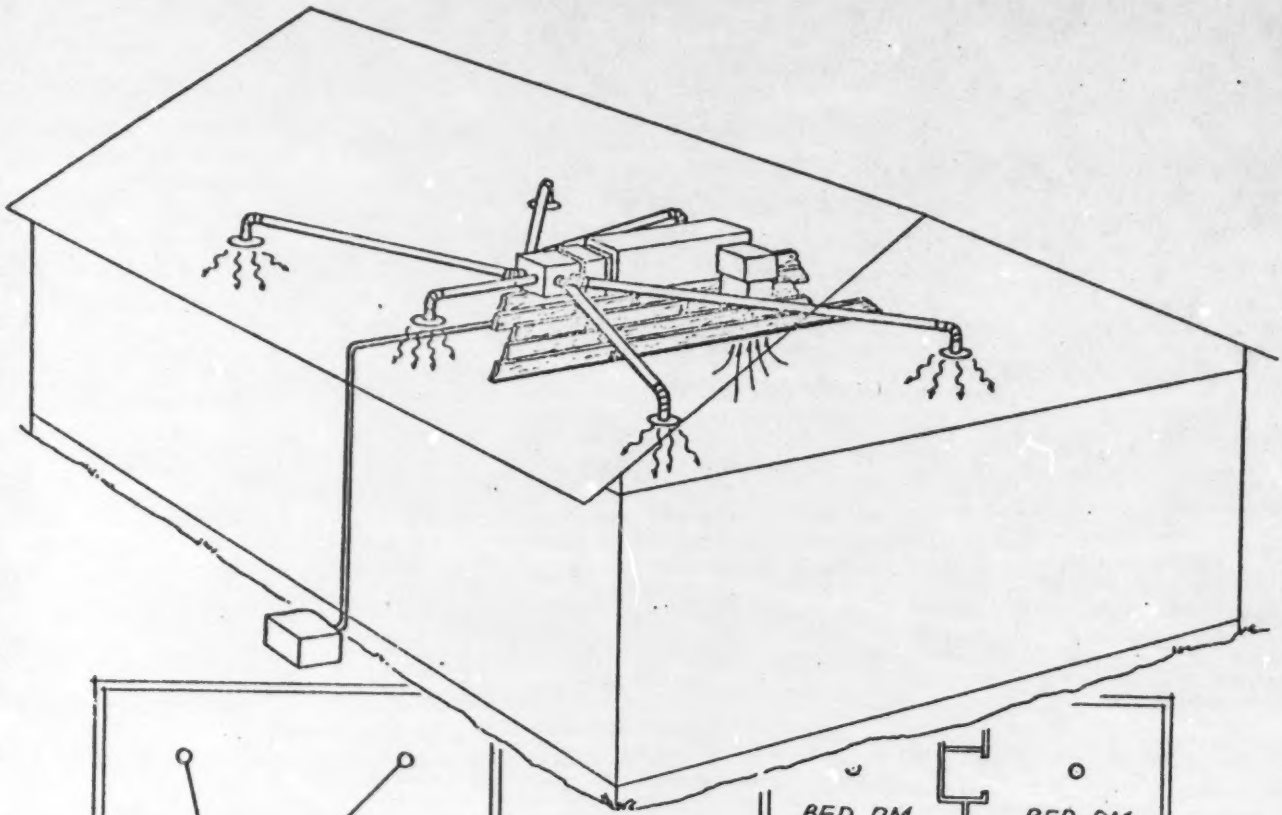


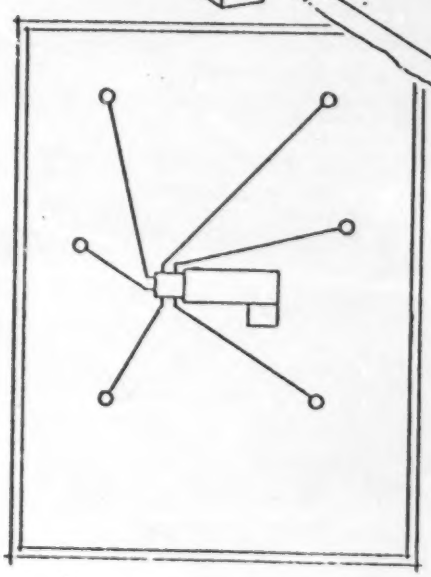
FIRST FLOOR PLAN

Figure 4.7

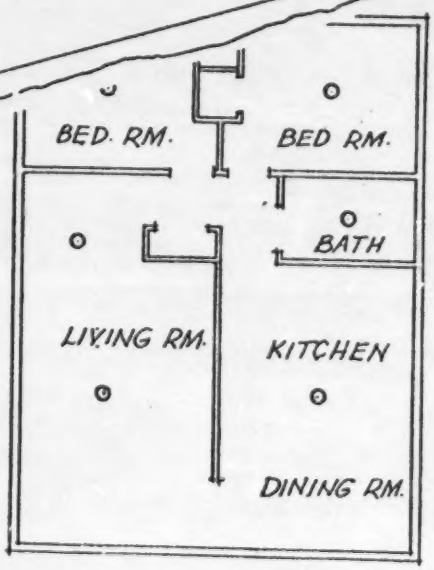
HORIZONTAL FURNACE IN ATTIC

In some installations, a gas horizontal furnace is installed in a properly ventilated attic. Little or no wall cutting is required; diffusers are installed in ceiling; return air grille in ceiling or high wall position. Also an excellent piping system for summer air conditioning. Use extended plenum or radial piping design. Plenums, ducts and pipes must be fully insulated.





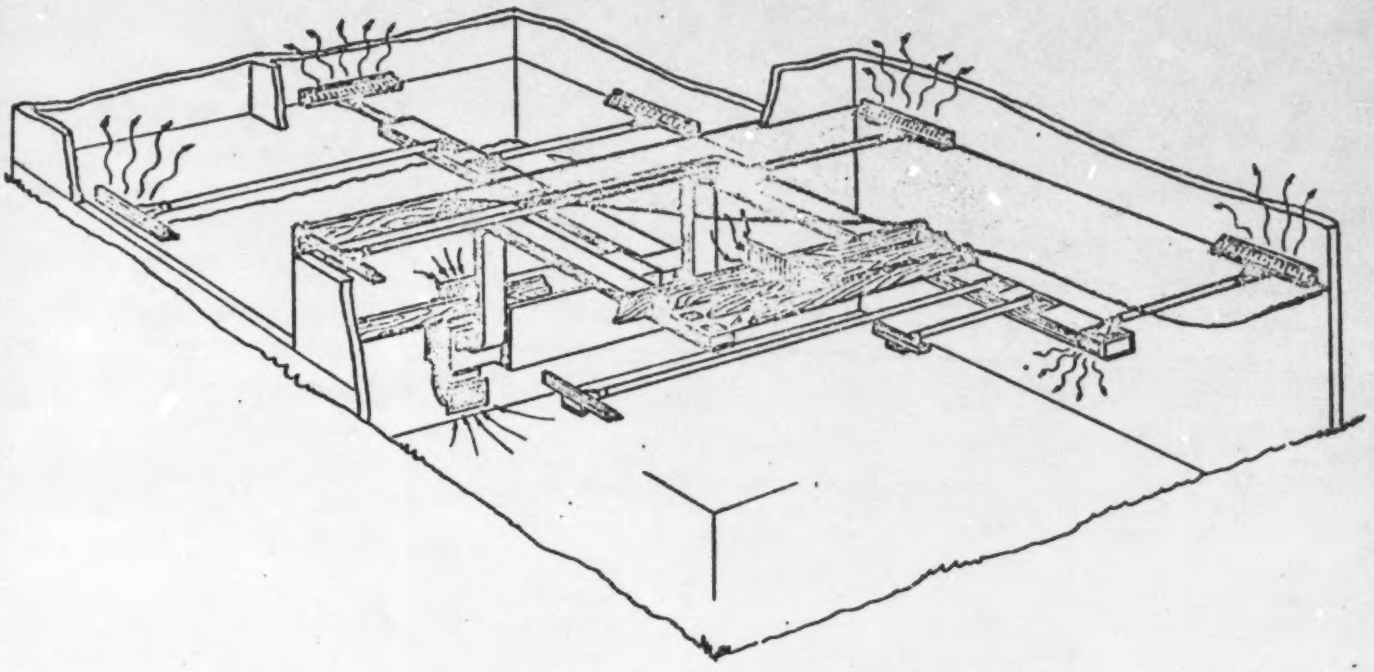
ATTIC PIPING PLAN

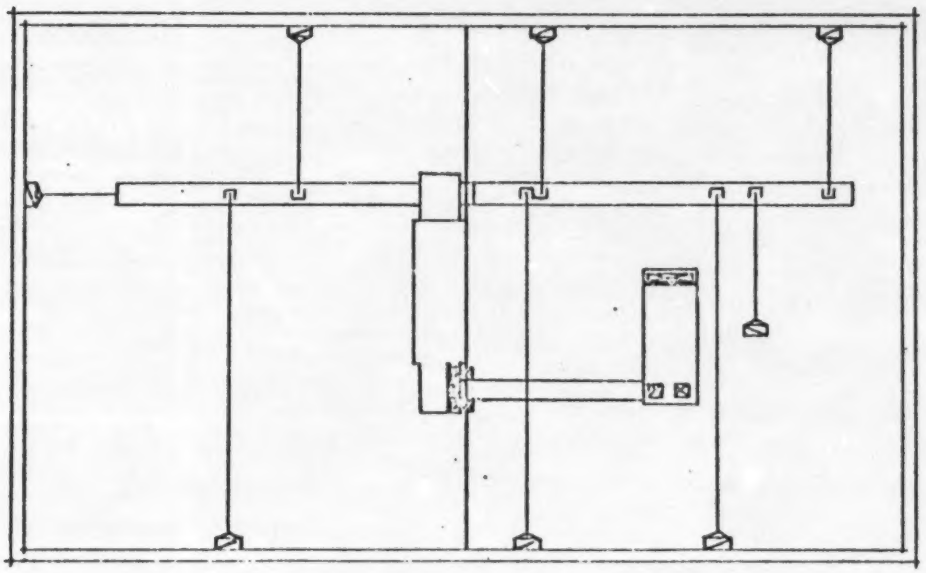


FIRST FLOOR PLAN

SPLIT-LEVEL HOUSES
Figure 4.8

In the illustration shown, a horizontal furnace is suspended from joists under second (ground) level. Ducts are run under floor joists of second and third levels. Branch supply pipes take off from top of ducts and run in joist spaces to baseboard diffusers. A register near end of the supply duct furnishes heat to the first level. Return air grilles are used at each level.



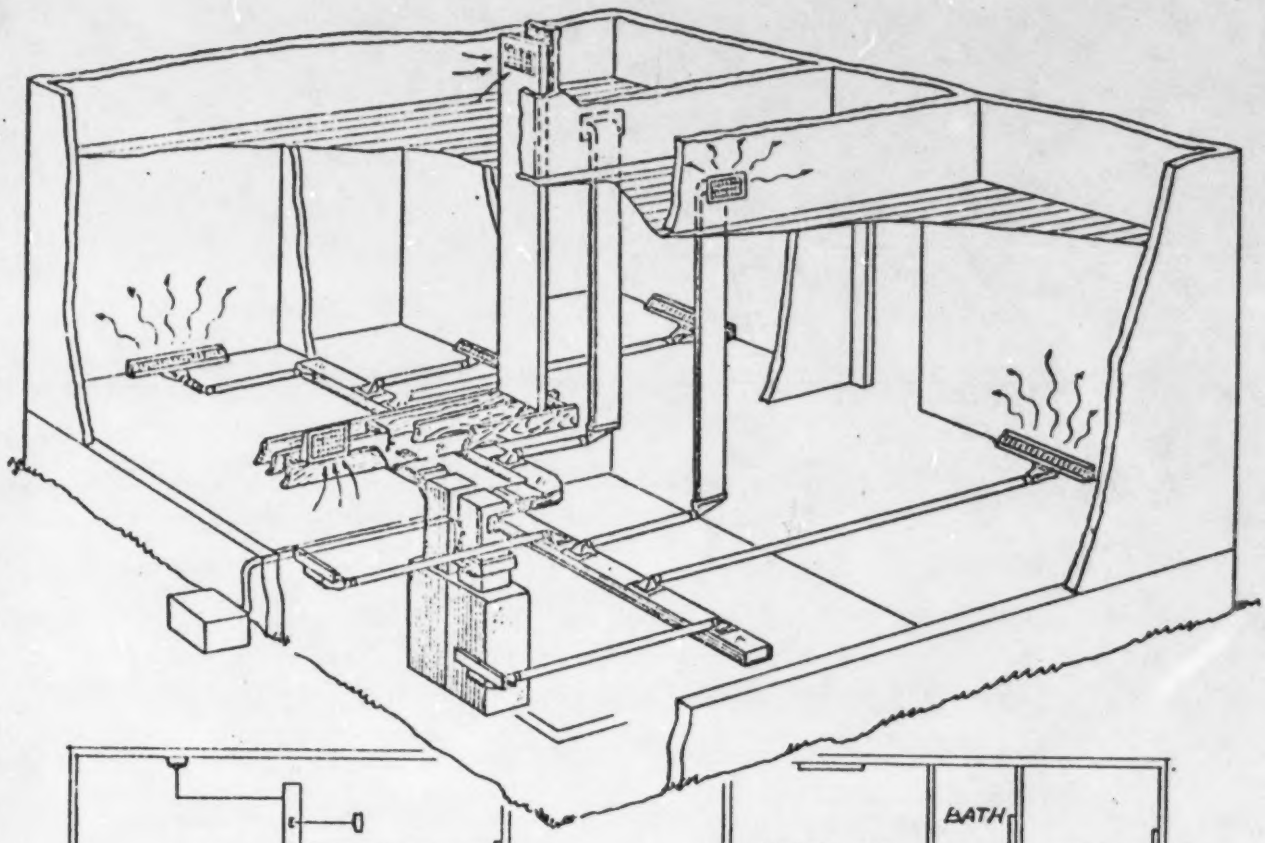


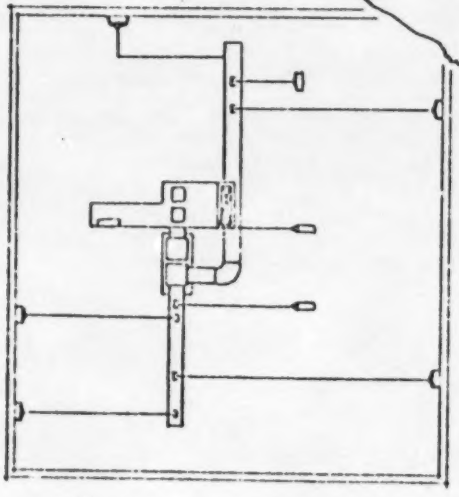
BASEMENT PIPING PLAN

AIR SYSTEMS
TWO-STORY HOUSES

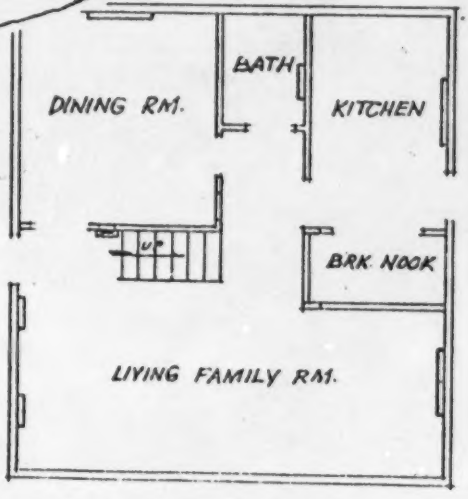
Figure 4.9

A basement lowboy furnace with an upflow cooling coil and outside condenser unit provide year around air conditioning for house shown. Conditioned air is distributed to first floor rooms through baseboard diffusers; second floor rooms are supplied by wall stacks extending through interior and connected to registers. A baseboard grille in downstairs hall and a high-wall grille in second floor collect return air, which drops into sheeted joist spaces.





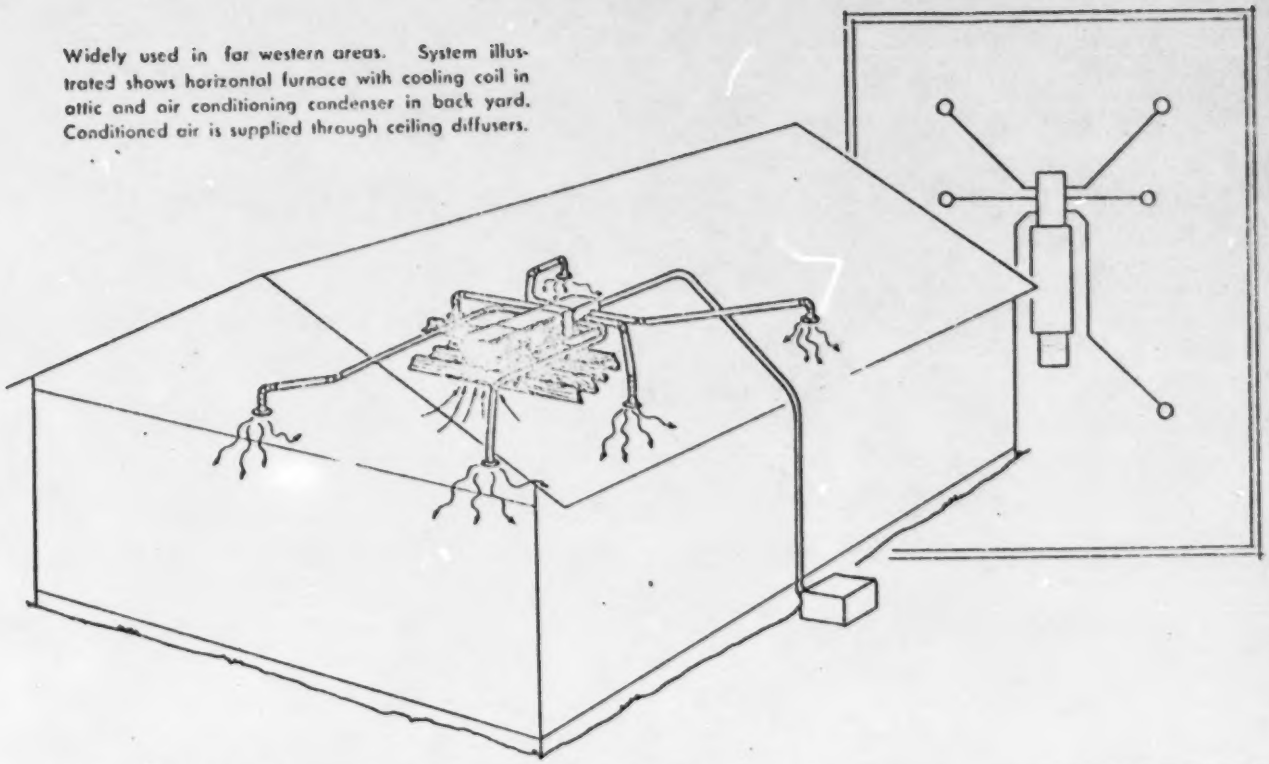
BASEMENT PIPING PLAN



FIRST FLOOR PLAN

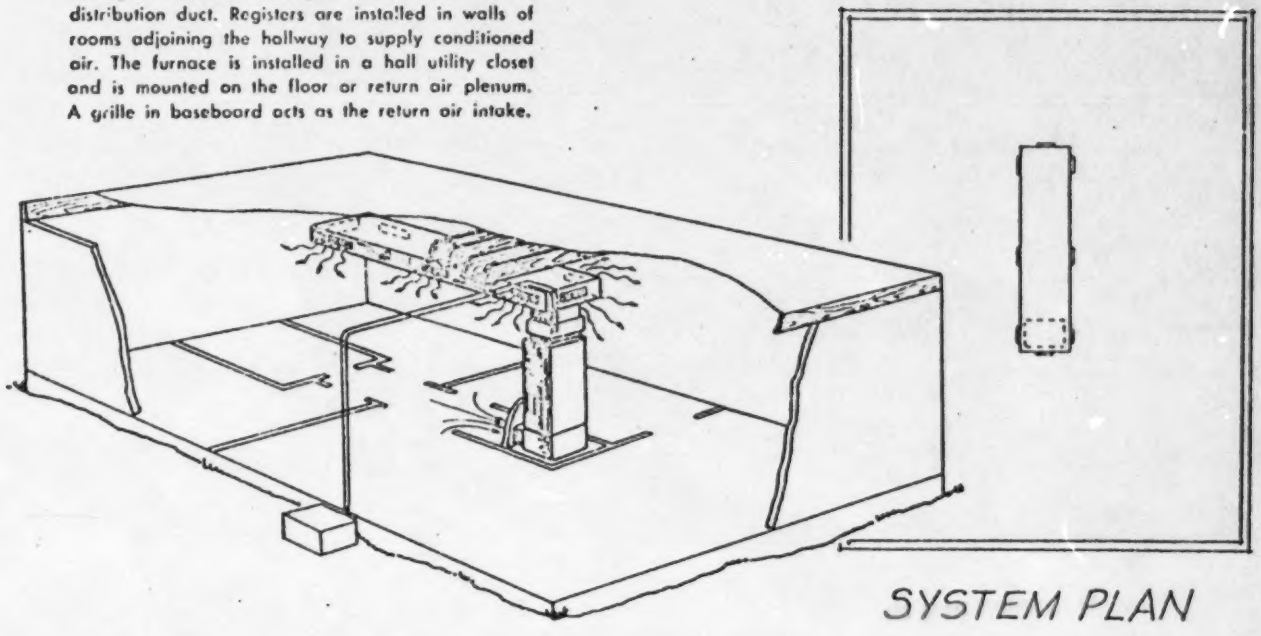
TYPICAL SYSTEMS
WEST PRACTICES
Figure 4.10

Widely used in far western areas. System illustrated shows horizontal furnace with cooling coil in attic and air conditioning condenser in back yard. Conditioned air is supplied through ceiling diffusers.



TYPICAL SYSTEMS
SOUTHWEST PRACTICES
Figure 4.11

In the milder climates of the southwest, a dropped ceiling in a central hallway is often used as a main distribution duct. Registers are installed in walls of rooms adjoining the hallway to supply conditioned air. The furnace is installed in a hall utility closet and is mounted on the floor or return air plenum. A grille in baseboard acts as the return air intake.



SYSTEM PLAN

D. INSULATION OF DUCTS

The ducts used to heat and air condition a home can be a major source of energy loss. In the winter, heat energy is lost from the ducts into cooler, unheated spaces; in the summer, heat energy is absorbed by the air-conditioning ducts passing through noninsulated spaces. Air-conditioning ducts are also susceptible to water condensation, and this can rust out a duct system in just a few years.

In heating systems, a duct running through any unheated area, such as an attic, garage, or unheated crawl space, should be insulated to reduce heat loss. While special duct-wrapping insulations are available for this purpose, you might find it more economical to use regular batting insulation. Normally, two inches or more of insulation is needed to adequately insulate heating ducts. The insulation should have a protective covering or backing; although a vapor barrier is usually not required over the outside of the insulation if the duct is used only for heating. If the heating ducts run through an insulated crawl space, the ducts will not usually require insulation. In the winter, the crawl space should be sealed off, so the temperature in the area will be high enough to prevent much heat loss through the exposed ducts.

Many new types of duct material are available. One type consists of fiberglass sheets that can be folded into a rectangle and taped in shape. The ends of each section are then notched and the pieces fitted together (like two pieces of pipe) and the seams are then taped to prevent air leakage. This fiberglass is

manufactured with a vapor barrier covering (usually silver in color).

When air-conditionig ducts run through any area that is not temperature controlled, the ducts must be insulated and covered with a vapor barrier. Exposed air-conditioning ducts not only increase your cooling load, they also cause the warm surrounding air to condense water vapor on the ducts, and this encourages rusting and other moisture problems. During the cooling season, the crawl space is generally cool enough that no moisture will condense on the ducts. If you do have a condensation problem, a simple solution is to cut an outlet in the duct system to blow some cool air into the crawl space. This method normally results in an insignificant increase in your cooling load because the crawl space is sealed, insulated and fairly cool to begin with. Just install a vent in the duct outlet so that you can regulate the amount of cool air that enters the crawl space, and be sure to close the vent during the winter heating season.

MODULE #10

HEATING, VENTILATING, AND AIR CONDITIONING
CONSERVATION OPPORTUNITIES

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FIGURE 1.1

ENERGY USE
PERCENT OF TOTAL U.S. ENERGY USE IN RESIDENTIAL SECTOR

WOOD	NIL
COAL	NIL
NATURAL GAS	7.3%
ELECTRICITY	7.5%
OIL	4.4%
TOTAL	19.2%

SPACE HEATING	11.0%	
WATER HEATING	2.9%	
AIR CONDITIONING	0.7%	15.7%
REFRIGERATION	1.1%	
COOKING	1.1%	
LIGHTING	0.7%	
OTHER (SMALL APPLIANCES)	1.7%	
TOTAL	19.2%	

DESIGN TEMPERATURES FOR HEATING

FIGURE 1.2

The following table lists the outdoor winter temperatures in common use in these areas. These are recommended for use as the basis for preparing heating estimates.

State & City	Design Temp. °F
ALABAMA	
Anniston	10
Birmingham	10
Gadsden	10
Mobile	20
Montgomery	20
Tuscaloosa	10
ALASKA	
Anchorage	-24
Barrow	-48
Bethel	-43
Fairbanks	-53
Juneau	-17
Kodiak	-5
McGrath	-8
Nome	-46
Nulato	-56
Seward	-4
Sitka	8
ARIZONA	
Bisbee	30
Flagstaff	-4
Globe	20
Nogales	30
Phoenix	35
Tucson	30
Winslow	-4
Yuma	40
ARKANSAS	
Bentonville	0
Fort Smith	5
Hot Springs	10
Little Rock	15
Pine Bluff	10
Texarkana	10
CALIFORNIA	
Bakersfield	30
Blue Canyon	35
Eureka	30
Fresno	30
Long Beach	35
Los Angeles	40
Montague	15
Needles	25
Oakland	30
Pasadena	40
Red Bluff	15
Sacramento	30
San Bernardino	30
San Diego	45
San Francisco	35
San Jose	40
COLORADO	
Boulder	-15
Colorado Springs	-10
Denver	-10
Durango	-5
Fort Collins	-15
Grand Junction	-5
Leadville	-15
Pueblo	-15
CONNECTICUT	
Bridgeport	0
Hartford	0
New Haven	0
New London	5
Norwich	0
Torrington	0
Waterbury	0
DELAWARE	
Dover	10
Milford	10
Wilmington	5
DIST. OF COLUMBIA	
Washington	15
FLORIDA	
Apalachicola	25
Fort Myers	40
Gainesville	30
Jacksonville	30
Key West	55
Miami	45
Orlando	35
Pensacola	25
Tallahassee	25
Tampa	35
GEORGIA	
Athens	10
Atlanta	10
Augusta	20
Brunswick	25
Columbus	20
Macon	20
Rome	10
Savannah	25
Way Cross	25
IDAHO	
Boise	-10
Idaho Falls	-15
Lewiston	-10
Pocatello	-15
Twin Falls	-15
ILLINOIS	
Aurora	-10
Bloomington	-10
Cairo	0
Champaign	-10
Chicago	-10
Evanston	-10
Peoria	-10
Pigeon	-15
Joliet	-10
Moline	-10
Peoria	-15
Rockford	-15
Rock Island	-10
Springfield	-10
Urbana	-10
INDIANA	
Elkhart	-10
Evansville	-5
Fort Wayne	-5
Indianapolis	-10
Lafayette	-10
South Bend	-10
Terre Haute	-5
IOWA	
Burlington	-10
Cedar Rapids	-15
Charles City	-20
Clinton	-15
Council Bluffs	-15
Davenport	-10
Des Moines	-15
Dubuque	-15
Fort Dodge	-15
Keokuk	-15
Mason City	-15
Sioux City	-15
Waterloo	-15
KANSAS	
Atchison	-10
Concordia	-10
Dodge City	-10
Hays	-5
Leavenworth	-10
Salina	-10
Topeka	-10
Wichita	-5
KENTUCKY	
Bowling Green	0
Covington	0
Hopkinsville	0
Lexington	0
Louisville	0
Owensboro	0
Shelbyville	0
LOUISIANA	
Alexandria	20
Baton Rouge	20
New Orleans	25
Shreveport	15
MAINE	
Augusta	-15
Bangor	-20
Bar Harbor	-10
Bethel	-10
Eastport	-10
Lewiston	-10
Millinocket	-15
Orono	-20
Portland	-10
Presque Isle	-20
Rumford	-15
MARYLAND	
Annapolis	10
Baltimore	10
Cambridge	10
Cumberland	0
Frederick	5
Frostburg	-5
Salisbury	10
MASSACHUSETTS	
Amherst	-5
Boston	0
Fall River	0
Fitchburg	-5
Framingham	-5
Lawrence	-5
Lowell	-5
Nantucket	0
New Bedford	0
Pittsfield	-10
Plymouth	0
Springfield	-5
Worcester	-5
MICHIGAN	
Alpena	-10
Ann Arbor	-5
Big Rapids	-5
Cadillac	-10
Calumet	-20
Detroit	-5
Escanaba	-20
Flint	-10
Grand Haven	-5
Grand Rapids	-5
Houghton	-20
Kalamazoo	-5
Lansing	-10
Ludington	-5
Marquette	-15
Muskegon	-5
Port Huron	-10
Saginaw	-10
Sault Ste. Marie	-20
MINNESOTA	
Alexandria	-25
Duluth	-25
Minneapolis	-25
Moorhead	-30
St. Cloud	-25
St. Paul	-25
MISSISSIPPI	
Biloxi	25
Columbus	10
Corinth	5
Hattiesburg	20
Jackson	15
Meridian	15
Natchez	15
Vicksburg	15
MISSOURI	
Columbia	-10
Hannibal	-10
Kansas City	-10
Kirksville	-10
St. Joseph	-10
St. Louis	-5
Springfield	-5
MONTANA	
Anaconda	-30
Billings	-30
Butte	-30
Great Falls	-40
Havre	-40
Helena	-40
Kalispell	-30
Miles City	-35
Missoula	-30
NEBRASKA	
Grand Island	-15
Hastings	-15
Lincoln	-15
Norfolk	-15
North Platte	-15
Omaha	-15
Valentine	-20
York	-15
NEVADA	
Elko	-10
Las Vegas	10
Reno	5
Tonopah	5
Winnemucca	-10
NEW HAMPSHIRE	
Berlin	-15
Claremont	-15
Concord	-10
Franklin	-15
Hanover	-15
Keene	-10
Manchester	-10
Nashua	-10
Portsmouth	-5
NEW JERSEY	
Asbury Park	5
Atlantic City	10
Bayonne	0
Belvidere	0
Bloomfield	0
Bridgeton	5
Camden	5
East Orange	0
Elizabeth	0
Jersey City	0
Newark	0
New Brunswick	5
Paterson	0
Phillipsburg	0
Trenton	0
NEW MEXICO	
Albuquerque	10
El Morro	0
Raton	-5
Roswell	5
Santa Fe	5
Tucumcari	5
NEW YORK	
Albany	-10
Auburn	-10
Binghamton	-5
Buffalo	-5
Canton	-20
Cortland	-10
Elmira	-5
Glens Falls	-15
Ithaca	-5
Jamestown	-5
Lake Placid	-15
New York	5
Niagara Falls	-5
Ogdensburg	-20
Oneonta	-10
Oswego	-5
Port Jervis	0
Rochester	-5
Schenectady	-10
Syracuse	-10
Watertown	-15
NORTH CAROLINA	
Asheville	5
Charlotte	15
Greensboro	10
Hatteras	20
New Bern	20
Raleigh	15
Salisbury	10
Wilmington	20
Winston-Salem	10
NORTH DAKOTA	
Bismarck	-30
Devils Lake	-30
Dickinson	-30
Fargo	-30
Grand Forks	-30
Jamestown	-30
Minot	-35
Pembina	-35
Williston	-35
OHIO	
Akron	-5
Cincinnati	-5
Cleveland	-5
Columbus	-5
Dayton	-5
Lima	-5
Marion	-5
Sandusky	-5
Toledo	-5
Warren	-5
Youngstown	-5
OKLAHOMA	
Ardmore	5
Bartlesville	-5
Guthrie	0
Muskogee	0
Oklahoma City	0
Tulsa	0
Waynoka	-5
OREGON	
Arlington	5
Baker	-15
Eugene	15
Medford	20
Pendleton	-10
Portland	10
Roseburg	20
Salem	15
Wamic	0
PENNSYLVANIA	
Altoona	-5
Bethlehem	0
Coatesville	5
Erie	-5
Harrisburg	5
New Castle	-5
Oil City	-5
Philadelphia	5
Pittsburgh	-5
Reading	5
Scranton	0
Warren	-5
Williamsport	-5
York	5
RHODE ISLAND	
Block Island	5
Bristol	0
Kingston	0
Pawtucket	0
Providence	0
SOUTH CAROLINA	
Charleston	20
Columbia	20
Florence	20
Greenville	10
Spartanburg	10
SOUTH DAKOTA	
Aberdeen	-25
Huron	-20
Pierre	-20
Rapid City	-20
Sioux Falls	-20
Watertown	-25
TENNESSEE	
Chattanooga	10
Jackson	5
Johnson City	0
Knoxville	5
Memphis	5
Nashville	5
TEXAS	
Abilene	5
Amarillo	0
Austin	15
Brownsville	30
Corpus Christi	25
Dallas	10
Del Rio	20
El Paso	20
Fort Worth	10
Galveston	25
Houston	20
Palestine	10
Port Arthur	20
San Antonio	20
Waco	10
UTAH	
Logan	-10
Milford	-5
Ogden	-5
Salt Lake City	0
VERMONT	
Bennington	-10
Burlington	-15
Montpelier	-20
Newport	-20
Northfield	-20
Rutland	-15
VIRGINIA	
Cape Henry	15
Charlottesville	10
Danville	10
Lynchburg	10
Norfolk	15
Petersburg	10
Richmond	10
Roanoke	5
Wytheville	5
WASHINGTON	
Aberdeen	20
Bellingham	10
Everett	15
North Head	20
Olympia	15
Seattle	15
Spokane	-15
Tacoma	15
Tatoosh Island	20
Walla Walla	-10
Wenatchee	-10
Yakima	-5
WEST VIRGINIA	
Bluefield	0
Charleston	0
Elkins	-5
Fairmont	0
Huntington	0
Martinsburg	0
Parkersburg	0
Wheeling	-5
WISCONSIN	
Ashland	-25
Beloit	-15
Eau Claire	-20
Green Bay	-20
La Crosse	-20
Madison	-20
Milwaukee	-15
Oshkosh	-20
Sheboygan	-20
WYOMING	
Casper	-25
Cheyenne	-20
Lander	-30
Sheridan	-30
Yellowstone Park	-35

DESIGN TEMPERATURES FOR AIR CONDITIONING

FIGURE 1.3

(OUTSIDE DRY- AND WET-BULB TEMPERATURES)

BEST COPY AVAILABLE

State & City	Summer DB	Summer WB
ALABAMA		
Anniston	95	78
Birmingham	95	78
Gadsden	95	78
Mobile	90	81
Montgomery	95	78
Tuscaloosa	95	78
ARIZONA		
Phoenix	105	72
Prescott	85	61
Tucson	105	72
Yuma	105	72
Flagstaff	85	61
Nogales	95	68
Bisbee	85	70
ARKANSAS		
Fort Smith	95	78
Little Rock	95	78
Hot Springs	95	78
Pine Bluff	95	78
Jonesboro	95	78
Texarkana	100	78
CALIFORNIA		
Bakersfield	105	78
Eureka	80	65
Fresno	105	78
Long Beach	95	78
Los Angeles	90	78
Pasadena	95	78
Redding	105	78
Sacramento	100	78
San Bernardino	105	78
San Diego	90	78
San Francisco	80	65
San Jose	90	78
COLORADO		
Denver	95	68
Colorado Springs	95	65
Denver	95	68
Durango	95	65
Fort Collins	95	65
Grand Junction	95	65
Pueblo	95	65
Trinidad	95	65
CONNECTICUT		
Bridgeport	85	75
Hartford	90	75
New Haven	85	75
New London	85	75
Norwalk	85	75
Stamford	90	75
Waterbury	90	75
DELAWARE		
Dover	90	78
Milford	95	78
Wilmington	90	78
DIST. OF COLUMBIA		
Washington	90	78
FLORIDA		
Daytona Beach	95	78
Fort Myers	95	78
Jacksonville	95	78
Key West	95	78
Miami	95	78
Orlando	100	78
Pensacola	95	78
St. Petersburg	95	78
Tallahassee	95	78
Tampa	95	78
West Palm Beach	95	78
GEORGIA		
Albany	95	78
Atlanta	95	76
Augusta	95	78
Columbus	100	78
Macon	95	78
Rome	95	78
Savannah	95	78
Thomasville	95	78
Valdosta	95	78
IDAHO		
Boise	100	72
Lewiston	95	72
Pocatello	95	68
Twin Falls	95	68
Coeur d'Alene	90	68
ILLINOIS		
Aurora	95	75
Bloomington	95	78
Cairo	100	78
Champaign	95	77
Chicago	95	75
Danville	95	77
Decatur	95	77
Elgin	95	78
Joliet	95	78
Moline	95	76
Peoria	95	76
Rockford	95	78
Rock Island	95	76
Springfield	95	77
Urbana	95	77
INDIANA		
Bluffton	95	75
Evansville	95	78
Fort Wayne	95	75
Indianapolis	95	76
Lafayette	95	76
South Bend	95	75
Terre Haute	95	78
IOWA		
Burlington	95	78
Cedar Rapids	95	78
Charles City	95	75
Clinton	95	78
Council Bluffs	100	78
Davenport	95	78
Des Moines	95	78
Dubuque	95	78
Fort Dodge	95	78
Keokuk	95	78
Marshalltown	95	78
Sioux City	95	78
Waterloo	95	78
KANSAS		
Atchison	100	76
Concordia	95	78
Dodge City	95	78
Ida	100	75
Leavenworth	100	76
Salina	100	78
Topeka	100	76
Wichita	100	75
KENTUCKY		
Bowling Green	95	78
Frankfort	95	78
Hopkinsville	95	78
Lexington	95	78
Louisville	95	78
Owensboro	95	78
Shelbyville	95	78
LOUISIANA		
Alexandria	95	78
Baton Rouge	95	80
New Orleans	95	80
Shreveport	95	78
MAINE		
Augusta	85	73
Bangor	85	73
Bar Harbor	85	73
Bethel	85	73
Eastport	85	73
Lewiston	85	73
Millinocket	85	73
Orono	85	73
Portland	85	73
Presque Isle	85	73
Rumford	85	73
MARYLAND		
Annapolis	90	78
Baltimore	90	78
Cambridge	90	78
Cumberland	90	75
Frederick	90	78
Frostburg	90	75
Salisbury	90	78
MASSACHUSETTS		
Amherst	90	75
Boston	85	75
Fall River	85	75
Fitchburg	90	75
Framingham	90	75
Lawrence	90	75
Lowell	85	75
Northfield	85	75
New Bedford	85	75
Pittsfield	90	75
Plymouth	85	75
Springfield	90	75
Worcester	90	75
MICHIGAN		
Alpena	90	75
Ann Arbor	90	75
Big Rapids	90	75
Cadillac	90	75
Calumet	80	73
Detroit	90	75
Escanaba	85	74
Flint	90	75
Grand Haven	90	75
Grand Rapids	90	74
Houghton	80	73
Kalamazoo	90	75
Lansing	90	75
Ludington	90	75
Marquette	80	73
Muskegon	90	74
Port Huron	90	75
Saginaw	90	75
Sault Ste. Marie	80	71
MINNESOTA		
Alexandria	85	74
Duluth	80	71
Minneapolis	90	75
Moorhead	95	75
St. Cloud	90	75
St. Paul	90	75
MISSISSIPPI		
Biloxi	90	80
Columbus	95	78
Corinth	95	78
Hattiesburg	95	80
Jackson	95	78
Meridian	95	79
Natchez	95	78
Vicksburg	95	78
MISSOURI		
Columbia	100	78
Hannibal	95	77
Kansas City	100	76
Kirksville	95	78
St. Joseph	100	76
St. Louis	95	78
Springfield	100	77
MONTANA		
Anaconda	85	69
Billings	90	66
Butte	85	69
Great Falls	90	63
Havre	95	70
Helena	90	63
Kalispell	90	63
Miles City	95	69
Missoula	90	63
NEBRASKA		
Grand Island	100	75
Hastings	100	75
Lincoln	95	78
Norfolk	95	78
North Platte	100	73
Omaha	100	78
Valentine	95	78
York	95	78
NEVADA		
Elko	95	63
Las Vegas	110	71
Reno	95	65
Tonopah	90	63
Winnemucca	95	65
NEW HAMPSHIRE		
Berlin	85	73
Claremont	85	73
Concord	85	73
Franklin	85	73
Hanover	85	73
Keene	85	73
Manchester	85	74
Nashua	85	74
Portsmouth	85	74
NEW JERSEY		
Asbury Park	90	78
Atlantic City	90	78
Bayonne	90	78
Belvedere	90	75
Bloomfield	90	75
Bridgeton	90	78
Camden	90	78
East Orange	90	75
Elizabeth	90	75
Jersey City	90	75
Newark	90	78
New Brunswick	90	75
Paterson	90	78
Phillipsburg	90	75
Trenton	90	78
NEW MEXICO		
Albuquerque	95	65
El Morro	85	65
Raton	95	65
Roswell	100	71
Santa Fe	90	65
Tucumcari	95	70
NEW YORK		
Albany	90	74
Auburn	90	74
Binghamton	90	72
Buffalo	85	73
Canton	85	73
Cortland	90	74
Elmira	90	73
Glens Falls	90	73
Ithaca	90	73
Jamestown	90	74
Lake Placid	90	73
New York	90	76
Niagara Falls	85	73
Ogdensburg	85	73
Oneonta	90	73
Oswego	90	74
Port Jervis	90	75
Rochester	90	74
Schenectady	90	74
Syracuse	90	74
Watertown	85	73
NORTH CAROLINA		
Asheville	90	75
Charlotte	95	78
Greensboro	90	76
Hatteras	90	80
New Bern	95	78
Raleigh	95	78
Salisbury	90	78
Wilmington	90	81
Winston-Salem	90	76
NORTH DAKOTA		
Bismarck	95	73
Devils Lake	90	70
Dickinson	95	70
Fargo	95	75
Grand Forks	90	72
Jamestown	95	73
Minot	90	71
Pembina	90	73
Williston	90	73
OHIO		
Akron	90	75
Cincinnati	95	78
Cleveland	90	75
Columbus	90	76
Dayton	90	76
Lima	90	75
Marion	90	75
Sandusky	90	75
Toledo	90	75
Warren	90	75
Youngstown	90	75
OKLAHOMA		
Ardmore	100	78
Bartlesville	100	77
Guthrie	100	77
Muskogee	95	79
Oklahoma City	100	77
Tulsa	100	77
Waynoka	105	75
OREGON		
Arlington	95	68
Baker	90	66
Eugene	90	68
Medford	95	68
Pendleton	90	66
Portland	85	68
Roseburg	90	66
Salem	90	68
Wamic	90	66
PENNSYLVANIA		
Altoona	90	75
Bethlehem	90	75
Coatesville	90	75
Erie	85	74
Harrisburg	90	75
New Castle	90	75
Oil City	90	75
Philadelphia	90	78
Pittsburgh	90	75
Reading	90	75
Scranton	90	75
Warren	90	75
Williamsport	90	75
York	90	75
RHODE ISLAND		
Block Island	85	75
Bristol	90	75
Kingston	85	75
Pawtucket	90	75
Providence	90	75
SOUTH CAROLINA		
Charleston	90	80
Columbia	95	78
Florence	95	79
Greenville	95	75
Spartanburg	95	78
SOUTH DAKOTA		
Aberdeen	95	75
Huron	100	75
Pierre	95	75
Rapid City	95	70
Sioux Falls	95	75
Watertown	95	75
TENNESSEE		
Chattanooga	95	78
Jackson	95	78
Johnson City	95	78
Knoxville	95	75
Memphis	95	78
Nashville	95	78
TEXAS		
Abilene	95	74
Amarillo	95	72
Austin	100	78
Brownsville	95	80
Corpus Christi	95	80
Dallas	100	78
Del Rio	100	78
El Paso	100	69
Fort Worth	100	78
Galveston	95	80
Houston	95	80
Palestine	100	78
Port Arthur	95	80
San Antonio	100	78
Waco	100	78
UTAH		
Logan	95	65
Milford	95	66
Ogden	90	65
Salt Lake City	95	65
VERMONT		
Bennington	90	73
Burlington	90	73
Montpelier	90	73
Newport	85	73
Northfield	90	73
Rutland	90	73
VIRGINIA		
Cape Henry	90	78
Charlottesville	90	78
Danville	90	78
Lynchburg	90	76
Norfolk	90	78
Petersburg	90	78
Richmond	90	78
Roanoke	90	76
Wytheville	90	76
WASHINGTON		
Aberdeen	85	64
Bellingham	80	65
Everett	80	65
North Head	80	65
Olympia	80	64
Seattle	80	65
Spokane	80	65
Tacoma	80	64
Tatoosh Island	80	65
Walla Walla	90	65
Wenatchee	90	65
Yakima	90	67
WEST VIRGINIA		
Bluefield	85	73
Charleston	90	75
Elkins	90	73
Fairmont	90	75
Huntington	90	76
Martinsburg	90	75
Parkersburg	90	75
Wheeling	90	75
WISCONSIN		
Ashland	80	71
Beloit	95	78
Eau Claire	90	75
Green Bay	90	75
La Crosse	95	75
Madison	90	75
Milwaukee	90	75
Oshkosh	90	75
Sheboygan	90	75
WYOMING		
Casper	90	62
Cheyenne	90	62
Lander	90	65
Sheridan	90	65
Yellowstone Park	85	62

FIGURE 2.1

HEATING SYSTEM

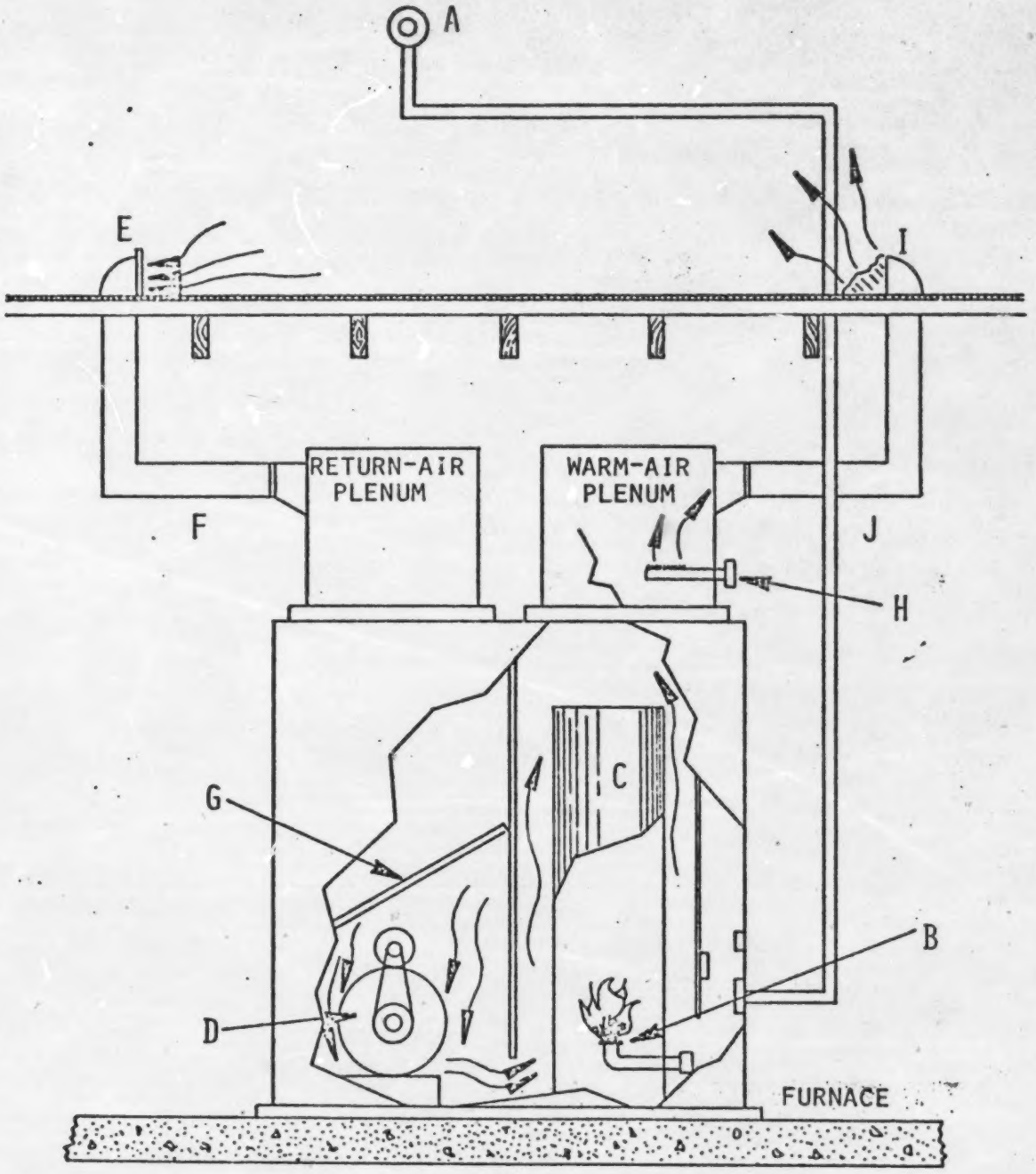

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FIGURE 2.2

DESIGN TEMPERATURES FOR HEATING

STATE AND CITY	DESIGN TEMP.° F
TEXAS	5°
ABILENE	0°
AMARILLO	15°
BROWNSVILLE	30°
CORPUS CHRISTI	25°
DALLAS	10°
DEL RIO	20°
EL PASO	20°
FORT WORTH	10°
GALVESTON	25°
HOUSTON	20°
PALESTINE	10°
PORT ARTHUR	20°
SAN ANTONIO	20°
WACO	10°

FIGURE 2.3

HEATING ESTIMATE WORK SHEET

TYPE OF HOUSE _____ STORY

1. ATTIC INSULATION ☐YES ☐NO
2. WALL INSULATION ☐YES ☐NO
3. STORM SASH ☐YES ☐NO

DESIGN TEMPERATURE
OUTSIDE _____ °F
INSIDE _____ °F
DIFFERENCE _____ °F

TYPE OF EXPOSURE		GROSS AREA IN SQUARE FEET	× MULTIPLIER	= HEAT LOSS IN BTU'S
EXPOSED WALLS		PERIMETER × CEILING HT. = SQ. FT. _____ × _____ =	×	=
GLASS	NO. OF WINDOWS NO. OF DOORS TOTAL GLASS	_____ × 15 = _____ × 20 = _____	×	=
COLD CEILING		LENGTH × WIDTH = SQ. FT. _____ × _____ =	×	=
COLD FLOOR			×	=

TOTAL HEAT LOSS IN BTU'S NEEDED AT REGISTER OR RADIATOR ⇨ _____

MULTIPLIERS

TYPE OF CONSTRUCTION		MULTIPLIERS FOR 70° AT OUTSIDE DESIGN TEMPERATURE						
		−30	−20	−10	0	+10	+20	+30
WALLS	FRAME OR BRICK VENEER STANDARD WALL							
	NO INSULATION	26	24	21	18	15	13	10
	WITH 3" OR MORE INSULATION	13	12	11	9	8	6	5
WINDOWS DOORS	PLAIN SINGLE GLASS	170	150	130	120	105	85	65
	WITH STORM SASH	80	70	60	55	50	40	30
CEILINGS	ATTIC ABOVE—NO INSULATION	32	29	25	22	19	15	12
	ATTIC ABOVE—3½" INSULATION	10	9	8	7	6	5	4
FLOORS	OVER BASEMENT (with furnace)	0	0	0	0	0	0	0
	OVER ENCLOSED CRAWL SPACE—4" INSULATION	5	5	4	4	3	3	2
	OVER ENCLOSED CRAWL SPACE—NO INSULATION	14	13	11	10	9	7	6
	OVER UNENCLOSED CRAWL SPACE	28	25	22	20	17	14	12
	ON A 4" CONCRETE SLAB	10	9	8	7	6	5	4

FIGURE 2.4

HEATING ESTIMATE WORK SHEET

DESIGN TEMPERATURE
OUTSIDE -15 °F
INSIDE +70 °F
DIFFERENCE +85 °F

TYPE OF HOUSE 1 STORY

ATTIC INSULATION ☒YES ☐NO
WALL INSULATION ☒YES ☐NO
STORM SASH ☒YES ☐NO

TYPE OF EXPOSURE		GROSS AREA IN SQUARE FEET				MULTIPLIER		HEAT LOSS IN BTU'S
EXPOSED WALLS		PERIMETER × CEILING HT. = SQ. FT.						
		148 × 8 = 1184			×	11	=	13,024
GLASS	NO. OF WINDOWS	10 × 15 = 150						
	NO. OF DOORS	2 × 20 = 40						
	TOTAL GLASS			190	×	130	=	24,700
COLD CEILING		LENGTH × WIDTH = SQ. FT.						
		46 × 28 = 1288			×	8	=	10,304
COLD FLOOR					×	0	=	0
TOTAL HEAT LOSS IN BTU'S NEEDED AT REGISTER OR RADIATOR							▶	48,028

MULTIPLIERS

TYPE OF CONSTRUCTION		MULTIPLIERS FOR 70° AT OUTSIDE DESIGN TEMPERATURE						
		−30	−20	−10	0	+10	+20	+30
WALLS	FRAME OR BRICK VENEER STANDARD WALL							
	NO INSULATION	26	24	21	18	15	13	10
	WITH 2" OR MORE INSULATION	13	12	(11)	9	8	6	5
WINDOWS DOORS	PLAIN SINGLE GLASS	170	150	(130)	120	105	85	65
	WITH STORM SASH	80	70	60	55	50	40	30
CEILINGS	ATTIC ABOVE—NO INSULATION	32	29	25	22	19	15	12
	ATTIC ABOVE—3½" INSULATION	10	9	(8)	7	6	5	4
FLOORS	OVER BASEMENT (with furnace)	0	0	(0)	0	0	0	0
	OVER ENCLOSED CRAWL SPACE—4" INSULATION	5	5	4	4	3	3	2
	OVER ENCLOSED CRAWL SPACE—NO INSULATION	14	13	11	10	9	7	6
	OVER UNENCLOSED CRAWL SPACE	28	25	22	20	17	14	12
	ON A 4" CONCRETE SLAB	10	9	8	7	6	5	4

HOW TO USE WORK SHEET

There is only one "cold" ceiling — the one immediately below the attic. "Cold" floors are over an open area, on a concrete slab, or over an unexcavated area. Measure the length and width of these surfaces. When you have the measurements and other information filled in, figure the areas by multiplying the length times the width, as indicated on the work sheet.

Total area of exposed walls is the house perimeter (distance in feet around the outside) times ceiling height. For houses with more than one story, total the ceiling heights of all levels except basement, before multiplying by perimeter.

Multiply each of these areas by its indicated construction factor called a "multiplier" . . . to be found in the "MULTIPLIERS" Table on the work sheet. The answers will be in BTUs and will show the heat loss. Equipment is rated in BTUs, so if the total heat loss of the house is known, it is easy to pick a furnace or boiler of the proper size from the *Wards* Catalog.

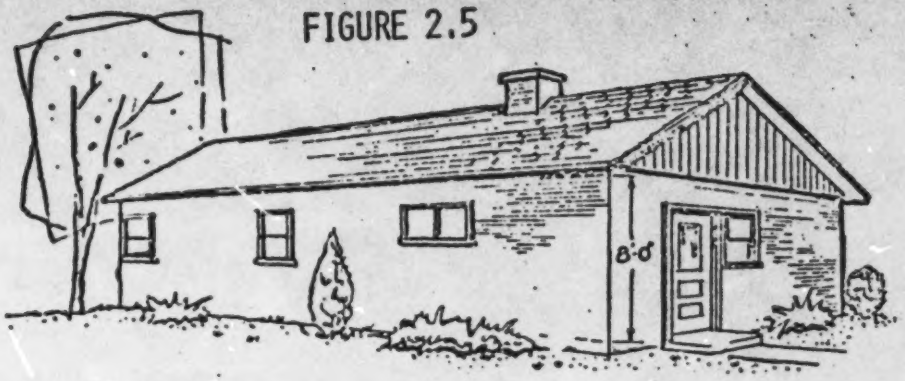
DETERMINING THE HEAT LOSS FOR A SAMPLE HOUSE

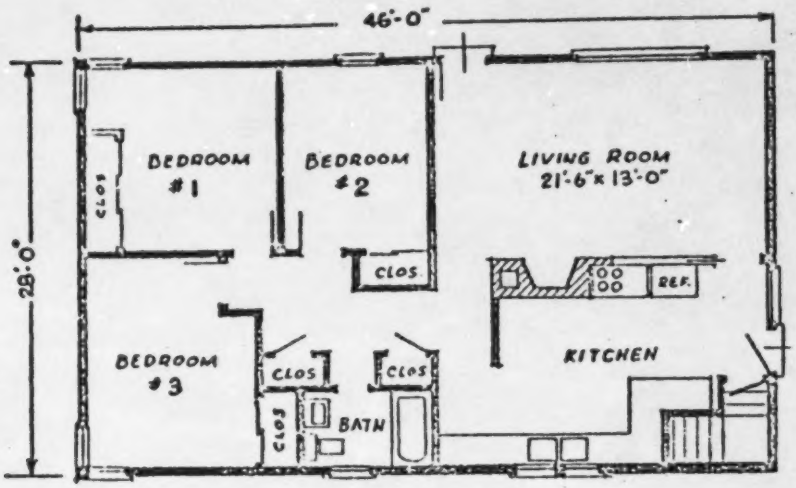
The Type of House

In estimating the heat loss of a sample house *(page 17)*, information and calculations are entered on the Work Sheet as shown above. Here is where they come from . . .

This is a single story house with a full basement. Both the walls and the attic have insulation, but the doors and windows are not protected by storm sash. The design temperature is -10°.

FIGURE 2.5





The Quick, Easy Calculations

WALLS Take the walls first. Walk around the house measuring its perimeter. In this example, it is 46 ft. *plus* 28 ft. *plus* 46 ft. *plus* 28 ft. or a total of 148 ft., which is entered on the form. Now, measure the ceiling height (8 ft). Multiplying these two figures (148 x 8) gives a total wall area of 1184 sq. ft.

Using the -10° column in the multiplier table, a figure of "11" is shown for insulated walls. Multiplying these figures (1184 x 11) gives a wall heat loss of 13,024 BTUs.

GLASS Count the number of windows (10) and multiply by "15." This gives a figure of 150 sq. ft. for windows. Similarly, count the number of doors (2) and multiply by "20" for a square foot figure of 40. Adding windows (150) and doors (40) gives a total glass area of 190. The multiplier for windows and doors without storm sash at -10° is "60". Multiplying these figures (190 x 130) gives the BTU heat loss of 24,700.

CEILING Ceiling area is the length of the house times its width (46 x 28) for a total of 1288 sq. ft. The multiplier for an insulated ceiling at -10° is "8." The heat loss of the ceiling then is (1288 x 8) or 10,304 BTUs.

FLOOR As the house has a full basement in which the furnace will be, the multiplier is "O". Therefore, the area of the floor need not be considered (since O x anything is still "O") ... and the heat loss through the floor is nothing ("O").

TOTAL HEAT LOSS This is just the sum of the individual heat losses (13,024 plus 24,700 plus 10,304 plus 0) which is a total of 48,028 BTUs. This indicates the total amount of heat (in BTUs) that will be needed in the house. To obtain this amount of heat requires a furnace with an output rating (at the registers) of 48,028 BTUs, or more.

FIGURE 2.6

COMMON FUELS AND THEIR HEAT ENERGY PER UNIT

FUEL	UNIT	BTU PER UNIT
NATURAL GAS	CUBIC FOOT	1,000
	THERM (100 CU FT)	100,000
PROPANE	GALLON	90,000
BUTANE	GALLON	130,000
No. 1 FUEL OIL	GALLON	136,000
No. 2 FUEL OIL	GALLON	140,000
ELECTRICITY	KILOWATT-HOUR	3,413

NOTE: PROPANE AND BUTANE ARE GASES THAT BECOME LIQUIDS WHEN THEY ARE PRESSURIZED, SO THEY ARE SOLD BY THE GALLON. LIQUID PETROLEUM GAS (LPG) IS A NAME COMMONLY APPLIED TO BOTH PROPANE AND BUTANE, OR EVEN A BLEND OF THE TWO. IN GENERAL, PROPANE IS USED IN THE NORTH WHILE BUTANE IS USED IN THE SOUTH.

FIGURE 2.7

HEATING SYSTEM EFFICIENCY

HEAT SOURCE	EFFICIENCY
WOOD FURNACE OR STOVE	30-50%
COAL FURNACE	30-60%
NATURAL GAS FURNACE	75-80%
PROPANE FURNACE	75-80%
BUTANE FURNACE	75-80%
OIL FURNACE	75-80%
ELECTRIC FURNACE	90-100%
ELECTRIC BASEBOARD	95-100%

FIGURE 3.1 AIR CONDITIONING SYSTEM

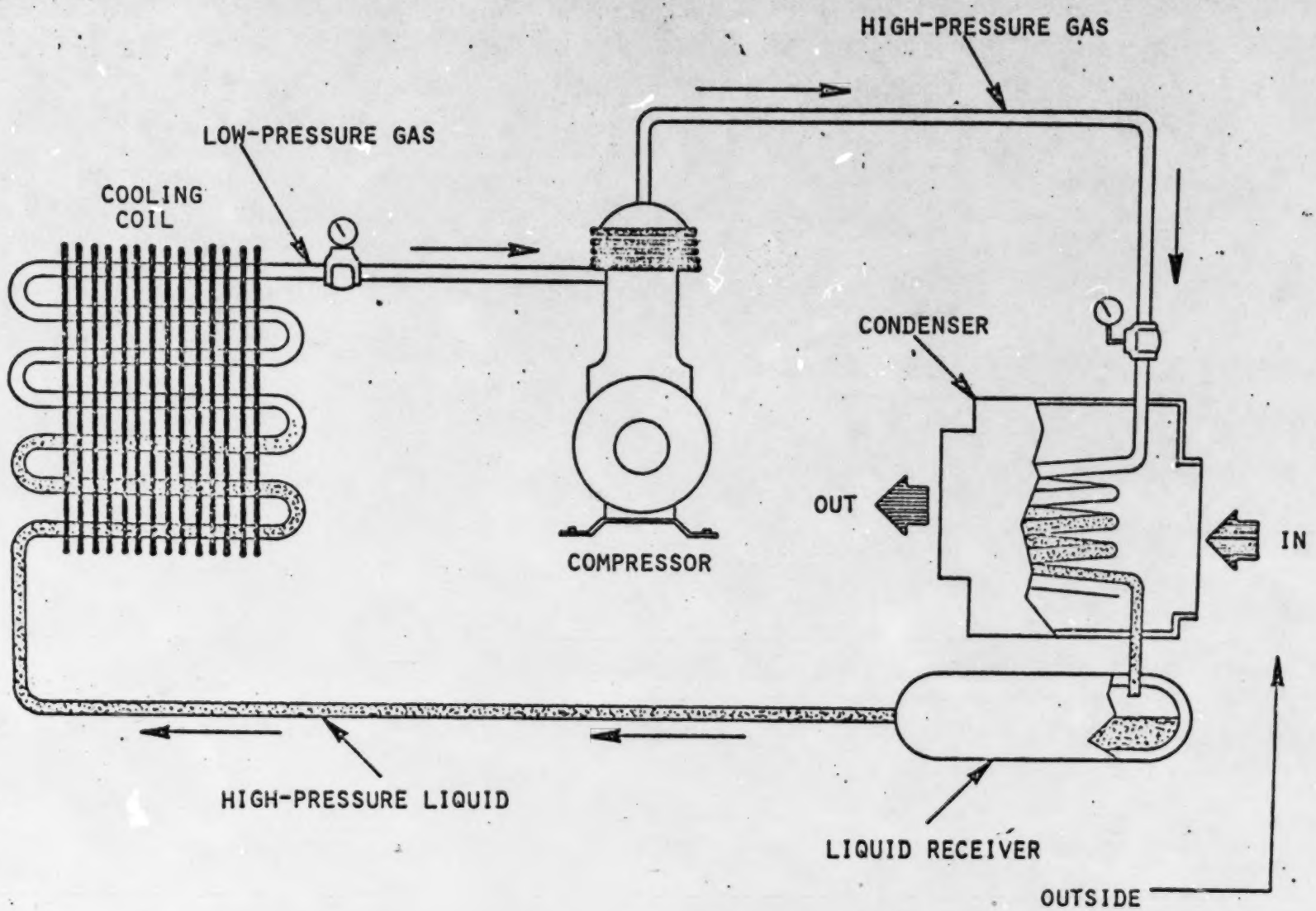


FIGURE 3.2

DESIGN TEMPERATURES FOR AIR CONDITIONING
(OUTSIDE DRY- AND WET-BULB TEMPERATURES)

STATE AND CITIES	SUMMER DB	SUMMER WB
TEXAS		
ABILENE	95	74
AMARILLO	95	72
AUSTIN	100	78
BROWNSVILLE	95	80
CORPUS CHRISTI	95	80
DALLAS	100	78
DEL RIO	100	78
EL PASO	100	69
FORT WORTH	100	78
GALVESTON	95	80
HOUSTON	95	80
PALESTINE	100	78
PORT ARTHUR	95	80
SAN ANTONIO	100	78
WACO	100	78

FIGURE 3.3

AIR CONDITIONING - ESTIMATE WORK SHEET

TYPE OF HOUSE _____ Story. Attic Insulated? _____ in.
SIZE OF HOUSE _____ X _____ Walls Insulated? _____ in.
WINDOWS SHADED? Awnings ☐ Venetian Blinds ☐ No ☐

DESIGN TEMPERATURES { DRY BULB _____ °F; INSIDE _____ °F; DIFFERENCE _____ °F } °WET BULB _____ °F

COOLING FACTORS

		ATTIC VENT. FAN	NATURAL VENTILATION DARK ROOF	NATURAL VENTILATION LIGHT ROOF
WITH ATTIC SPACE	NO INSULATION	9	13	10
	2" INSULATION	3	6	5
	4" INSULATION	2	3	3
BUILT UP ROOF NO ATTIC SPACE	NO INSULATION		23	18
	2" ROOF INSULATION		11	9
	3" ROOF INSULATION		8	7
CEILING UNDER WARM ROOM, NO INSULATION			4	
FRAME OR BRICK VENEER OR STUCCO	NO INSULATION		8	
	1" INSULATION OR ONE REFLECTIVE AIR SPACE		6	
	2" INSULATION OR TWO REFLECTIVE AIR SPACES		4	
	3½" INSULATION OR THREE REFLECTIVE AIR SPACES		3	
8" BRICK OR BLOCK	PLAIN OR PLASTERED DIRECT		10	
	FURRED, LATH & PLASTER, NO INSULATION		6	
	FURRED, 1" INSULATION OR ONE REFLECTIVE AIR SPACE		4	
	FURRED 2" INSULATION OR TWO REFLECTIVE AIR SPACES		3	
	FURRED, 3½" INSULATION OR THREE REFLECTIVE AIR SPACES		2	
12" ADOBE WALL			5	
OVER WARM ROOM			5	
OVER BASEMENT OR SLAB FLOOR OR CLOSED CRAWL SPACE			0	
OVER OPEN CRAWL SPACE			7	

NOTE MOST OF THE ABOVE FACTORS WERE DERIVED FROM MANUAL J PUBLISHED BY THE NATIONAL WARM AIR HEATING & AIR CONDITIONING ASS'N

SELECT FROM THESE FACTORS IN ESTIMATING COOLING LOAD AT RIGHT.

COOLING ESTIMATE

TYPE OF EXPOSURE	COOLING FACTORS	X	AREA	=	B.T.U. /hr.
PEOPLE - FIGURE 2 PEOPLE PER BEDROOM	400	X	Number	=	
CEILING		X	Lgth X Width	=	
EXPOSED WALLS — GROSS AREA		X	Perim X Ceil Ht.	=	
PARTITION — NEXT TO WARM ROOM — GROSS AREA	6.5	X	Lgth X Ceil Ht.	=	
FLOOR (ONLY OVER WARM AREA)		X	Lgth X Width	=	
KITCHEN - INCLUDE IN TOTAL →					1,500
GLASS - WINDOWS AND DOORS			No. Windows X 15 or Area		
NORTH, OR COMPLETE SHADE	40	X		=	
SOUTH, UNSHADED	65	X		=	
SOUTH, VEN. BLINDS OR DRAPES	45	X		=	
EAST AND WEST UNSHADED	117	X		=	
EAST AND WEST VEN BLINDS OR DRAPES	80	X			
WOOD DOORS	16	X	No. Doors X 30	=	
TOTAL — Based on 30° Temperature Difference (Total Includes Moisture Removal Load)					
YOUR DESIGN TEMPERATURE CORRECTION FOR: 15° = .75 | 25° = 1.25 | 30° = 1.50 | 35° = 1.75				X	
* CORRECTION FOR HIGH HUMIDITY AREAS: If Wet Bulb Temp. is 78° Add 5%; If Wet Bulb Temp. is 80° Add 10%					
TOTAL					

FIGURE 3.4

AIR CONDITIONING - ESTIMATE WORK SHEET

TYPE OF HOUSE Two Story. Attic Insulated? 3 3/8 in.
SIZE OF HOUSE 25'x28' Walls Insulated? 2 in.
WINDOWS SHADED? Awnings X Venetian Blinds ☐ No ☐

DESIGN TEMPERATURES: DRY BULB 100 °F; INSIDE 75 °F; DIFFERENCE 25 °F; *WET BULB 78 °F

COOLING FACTORS

		ATTIC VENT. FAN	NATURAL VENTILATION DARK ROOF	NATURAL VENTILATION LIGHT ROOF
WITH ATTIC SPACE	NO INSULATION	9	13	10
	2" INSULATION	3	6	5
	4" INSULATION	2	(3)	3
BUILT UP ROOF NO ATTIC SPACE	NO INSULATION		23	18
	2" ROOF INSULATION		11	9
	3" ROOF INSULATION		8	7
CEILING UNDER WARM ROOM, NO INSULATION			4	
FRAME OR BRICK VENEER OR STUCCO	NO INSULATION		8	
	1" INSULATION OR ONE REFLECTIVE AIR SPACE		6	
	2" INSULATION OR TWO REFLECTIVE AIR SPACES		(4)	
	3½" INSULATION OR THREE REFLECTIVE AIR SPACES		3	
8" BRICK OR BLOCK	PLAIN OR PLASTERED DIRECT		10	
	FURRED, LATH & PLASTER, NO INSULATION		6	
	FURRED, 1" INSULATION OR ONE REFLECTIVE AIR SPACE		4	
	FURRED 2" INSULATION OR TWO REFLECTIVE AIR SPACES		3	
	FURRED, 3½" INSULATION OR THREE REFLECTIVE AIR SPACES		2	
	12" ADOBE WALL		5	
OVER WARM ROOM			5	
OVER BASEMENT OR SLAB FLOOR OR CLOSED CRAWL SPACE			0	
OVER OPEN CRAWL SPACE			7	

NOTE MOST OF THE ABOVE FACTORS WERE DERIVED FROM MANUAL 3 PUBLISHED BY THE NATIONAL WARM AIR HEATING & AIR CONDITIONING ASS'N

SELECT FROM THESE FACTORS IN ESTIMATING COOLING LOAD AT RIGHT.

COOLING ESTIMATE

TYPE OF EXPOSURE	COOLING FACTORS		AREA	=	B.T.U./Hr.
PEOPLE – FIGURE 2 PEOPLE PER BEDROOM	400	X	Number 5	=	2000
CEILING	3	X	Lgth X Width 28x25	=	2100
WOOD WALL GROSS AREA	4	X	Perim X Ceil Ht 106x16	=	6784
PARTITION – NEXT TO WARM ROOM GROSS AREA	6.5	X	Lgth X Ceil Ht	=	
FLOOR (ONLY OVER WARM AREA)		X	Lgth X Width	=	
KITCHEN – INCLUDE IN TOTAL →					1,500
GLASS – WINDOWS AND DOORS			No. Windows X 15 or Area		
NORTH, OR COMPLETE SHADE	40	X	17X15	=	10200
SOUTH, UNSHADED	65	X		=	
SOUTH, VEN. BLINDS OR DRAPES	45	X		=	
EAST AND WEST UNSHADED	117	X		=	
EAST AND WEST VEN. BLINDS OR DRAPES	80	X		=	
WOOD DOORS	16	X	No. Doors X 20 2X20	=	640
TOTAL – Based on 20° Temperature Difference (Total Includes Moisture Removal Load) ▷					23224
YOUR DESIGN TEMPERATURE CORRECTION FOR 15° = .75 | 25° = 1.25 | 30° = 1.50 | 35° = 1.75				X	1.25
					29030
*CORRECTION FOR HIGH HUMIDITY AREAS If Wet Bulb Temp. is 78° Add 5% If Wet Bulb Temp. is 80° Add 10%					1451
TOTAL ▷					30481

DETERMINING THE COOLING FOR A SAMPLE HOUSE

Enter your information and calculations on the Work Sheet as shown following:

PEOPLE This 3-bedroom home will normally house 5 people, which multiplied by the factor "400", gives a cooling load of 5 x 400 or 2000 BTU/Hr.

CEILING The area is length of house times width (28 x 25) or 700 sq. ft. The ceiling cooling factor, for a dark color roof and attic space with between 2-in. and 4-in. insulation, is "3". The load then is 700 x 3 or 2100 BTU/Hr.

FIGURE 3.5

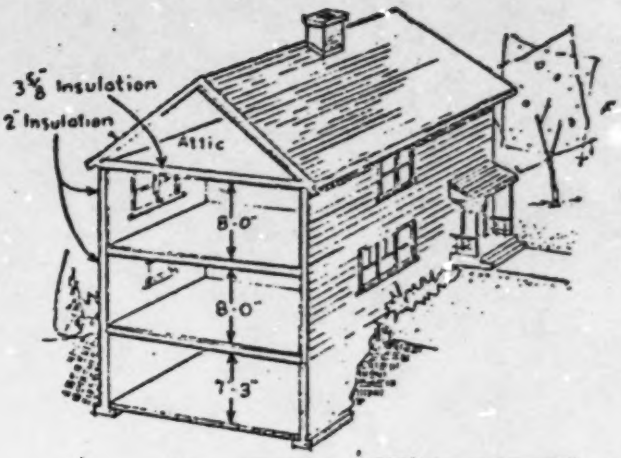
HOUSE SPECIFICATIONS

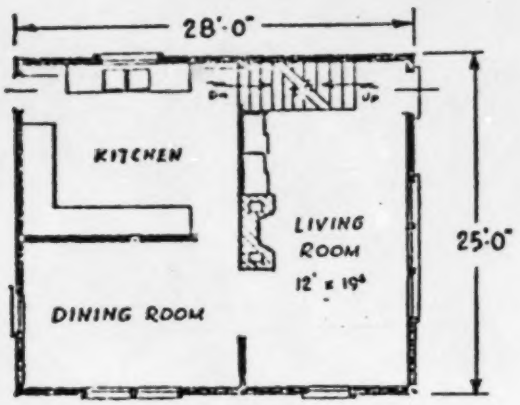
DESIGN TEMPERATURES

100° Dry Bulb – 75° Inside = 25° Difference

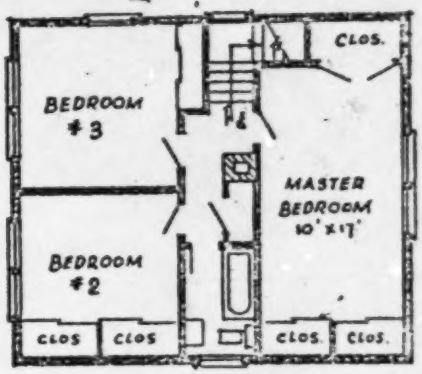
78° Wet Bulb Temp.

Roof	Dark Color
Walls	Frame With 2" Insulation
Ceiling	With Attic and 3 5/8" Insulation
Windows	All North or With Awnings
Basement	Under Entire House





FIRST FLOOR



SECOND FLOOR

EXPOSED WALLS Total area of exposed walls is perimeter of house times ceiling height (of upper ceiling). This is 106 (25+28+25+28) times 16 (2 stories) or 1,696 sq. ft. The cooling factor table shows frame walls with 2-in. insulation has the factor "4". Multiplying 1,696 sq. ft. by 4 gives a load of 6,784 BTU/Hr.

FLOOR Over basement . . . no factor required.

WINDOWS House has 17 windows, either facing north or completely shaded by awnings. This means that all windows will have a cooling factor of "40". First, multiply the 17 windows by "15" for glass area (17 x 15 = 255), then by 40 (255 x 40 = 10,200). This means that the cooling load for glass is 10,200 BTU/Hr.

WOOD DOORS The 2 wood doors to the outside are multiplied by "20" for area (2 x 20 = 40), then by the indicated factor "16" (40 x 16 = 640) for a load of 640 BTU/Hr.

KITCHEN A standard load of 1,500 BTU/Hr. is added for kitchen activities.

TOTAL COOLING LOAD (based on 20° temperature difference) This is the total of the preceding individual loads. In this example, it is 2,000 + 2,100 + 6,784 + 10,200 + 640 + 1,500 or 23,224 BTU/Hr.

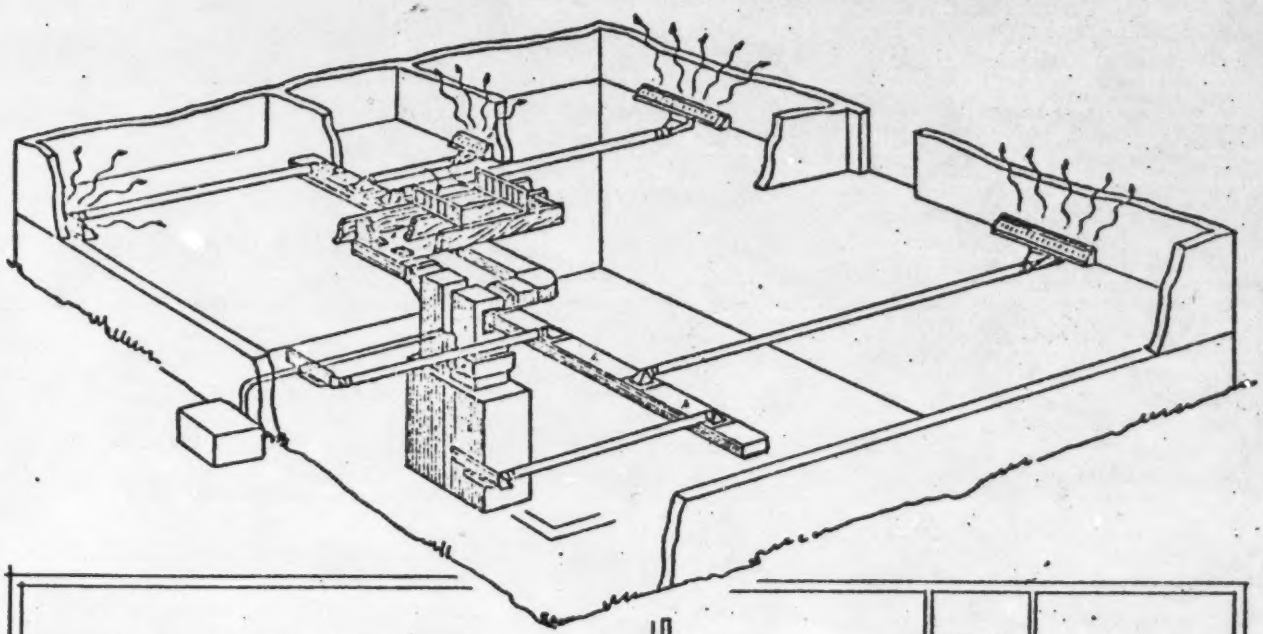
DESIGN TEMPERATURE CORRECTION An allowance must be made because the difference between the outside dry bulb temperature (100°) and the desired inside temperature (75°) is greater than 20°. The Work Sheet indicates that a difference of 25° (100° – 75°) requires a correction factor of 1.25. The adjusted cooling load (23,224 x 1.25) then becomes 29,030 BTU/Hr.

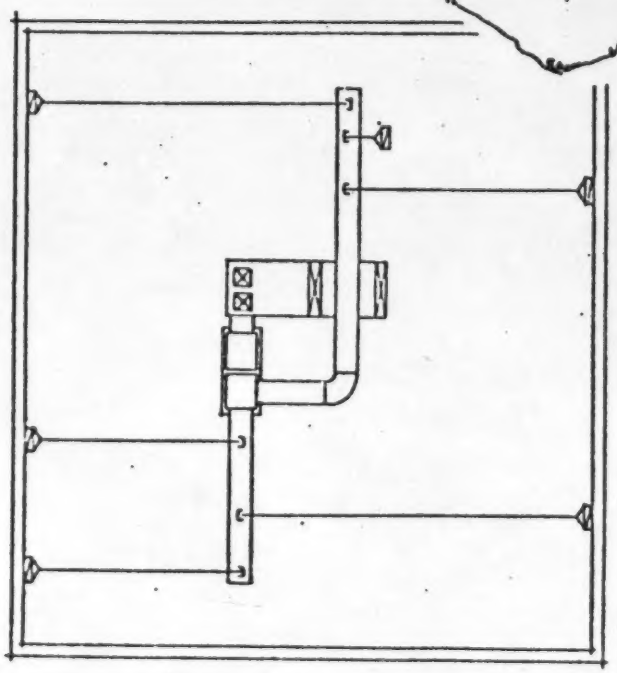
HIGH HUMIDITY CORRECTION This area has a wet bulb reading of 78°. The Work Sheet indicates that under such conditions, 5% must be added to the cooling load (29,030 x .05 = 1451; 29,030 + 1451 = 30,481). The final cooling load then becomes 30,481 BTU/Hr.

ONE-STORY HOUSE
WITH BASEMENT
Figure 4.1

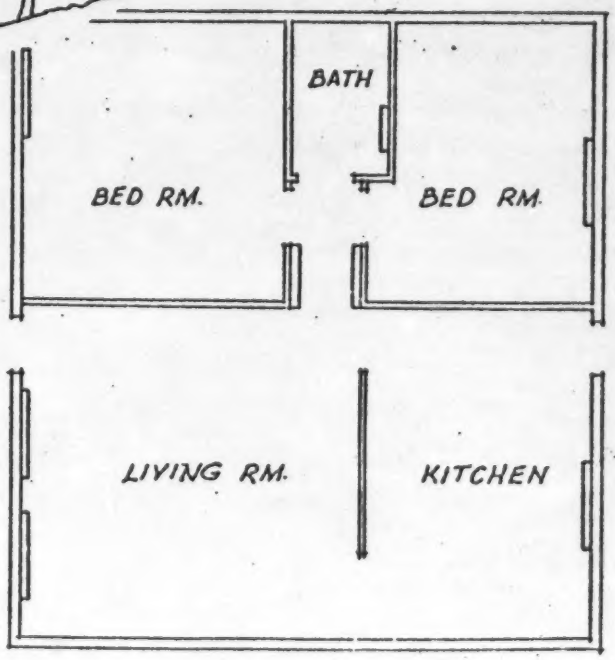
EXTENDED PLENUM SYSTEM

The extended plenum system usually is preferred for basement installation because of its neat appearance. Branch pipes to outlets may be round or rectangular and are run between or beneath basement joists. The extended plenum is usually required for larger installations.





BASEMENT PIPING PLAN

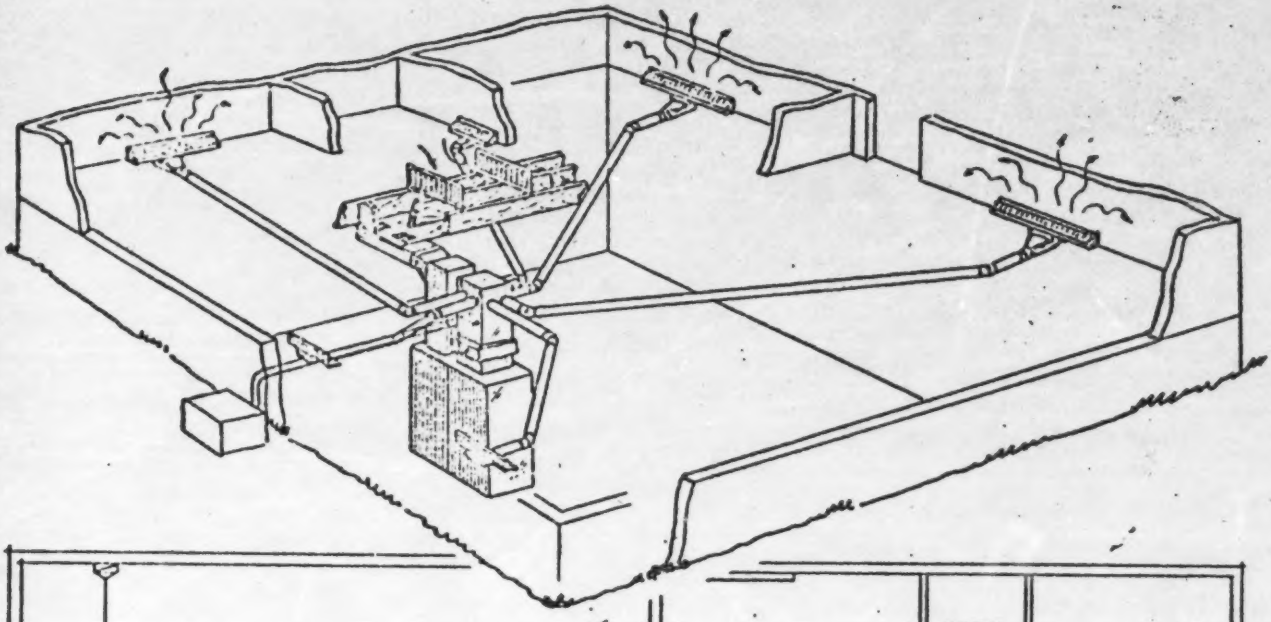


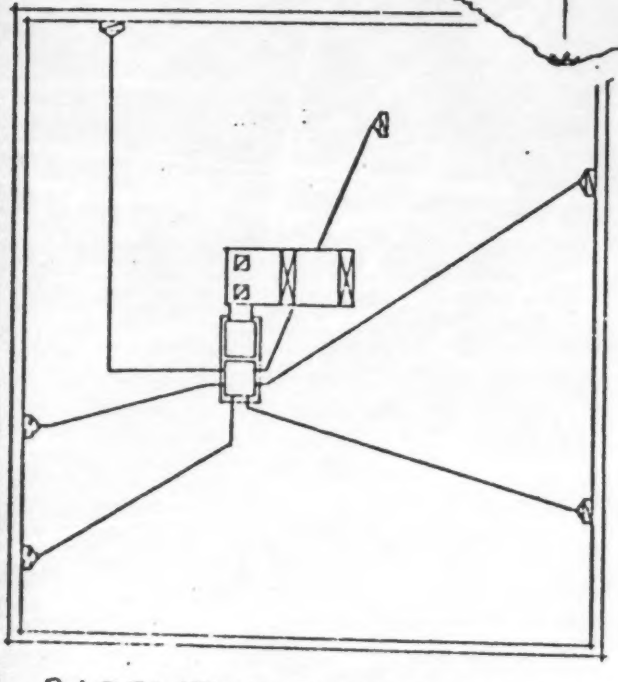
FIRST FLOOR PLAN

Figure 4.2

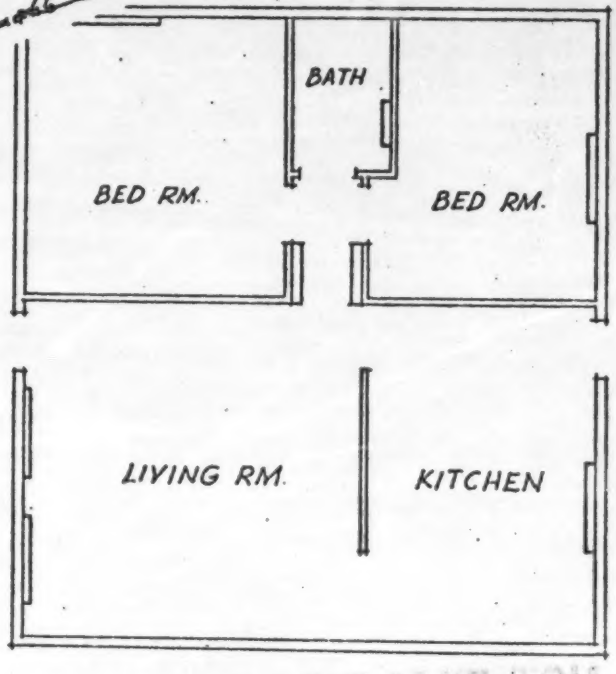
RADIAL PIPING SYSTEM

This method of piping can be used where length of individual pipe runs does not exceed limits of pipe capacity and where appearance is not a factor. Pipes are suspended from basement joists and run in as direct a line as possible from plenum to outlet connection. Requires a minimum amount of pipe.





BASEMENT PIPING PLAN

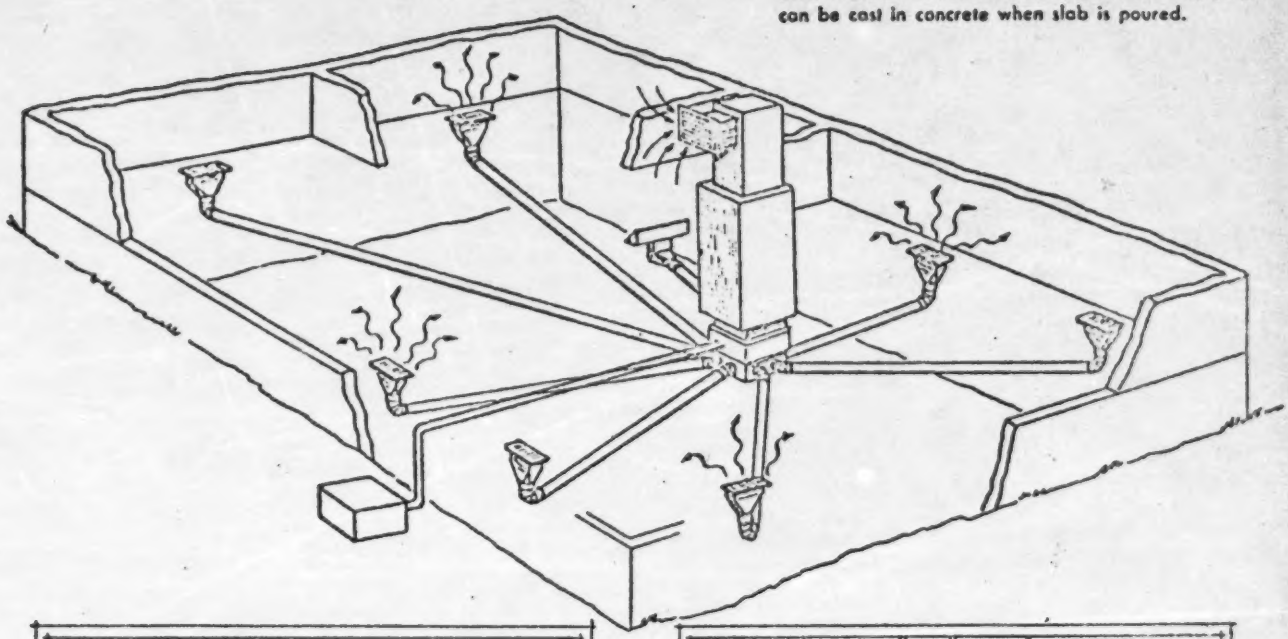


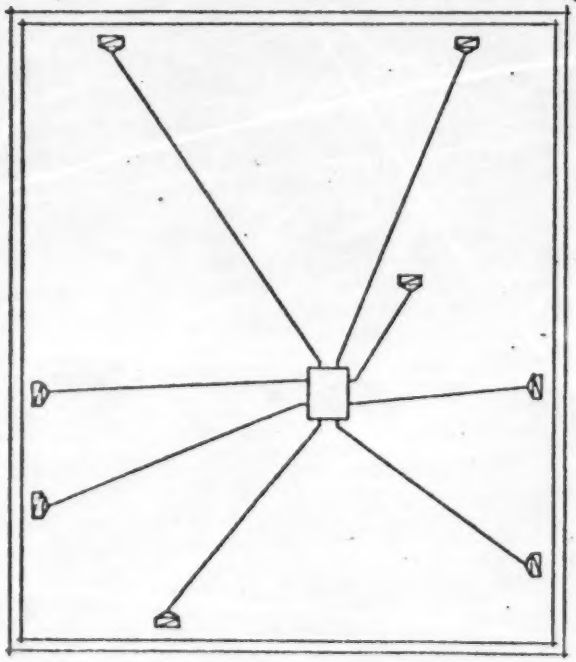
FIRST FLOOR PLAN

ONE-STORY HOUSE
WITH CRAWL SPACE
Figure 4.3

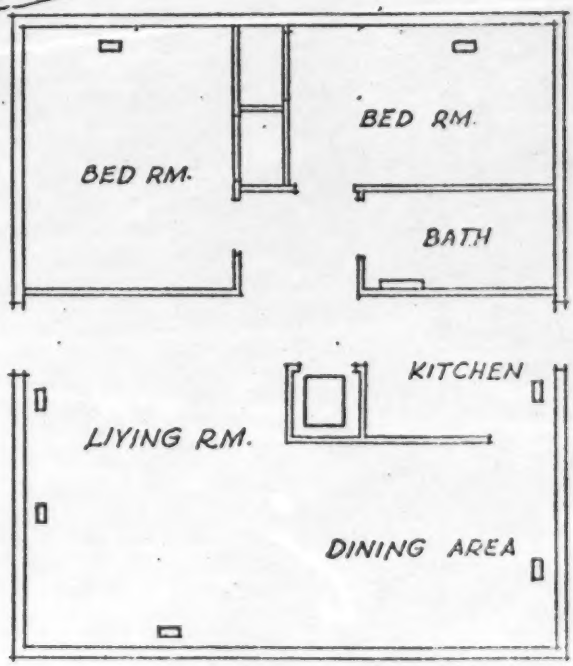
RADIAL PIPING SYSTEM, COUNTERFLOW FURNACE

This combination is widely used in compact, one-story houses with crawl space. Warm air plenum under furnace extends into crawl space, where pipes to supply outlets are run beneath joists. Supply pipes and plenum should be insulated. Similar system is used with slab construction where plenum and piping can be cast in concrete when slab is poured.





CRAWL SPACE PIPING PLAN



FIRST FLOOR PLAN

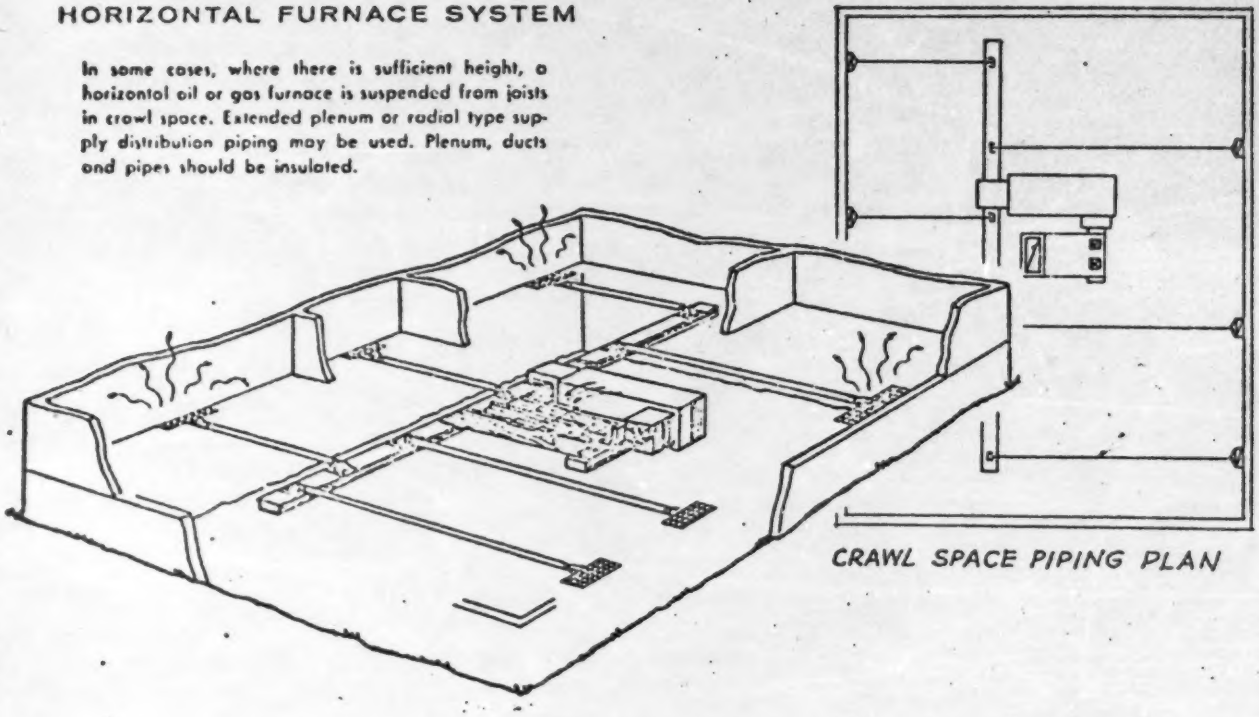
R

AIR SYSTEMS

Figure 4.4

HORIZONTAL FURNACE SYSTEM

In some cases, where there is sufficient height, a horizontal oil or gas furnace is suspended from joists in crawl space. Extended plenum or radial type supply distribution piping may be used. Plenum, ducts and pipes should be insulated.



CRAWL SPACE PIPING PLAN

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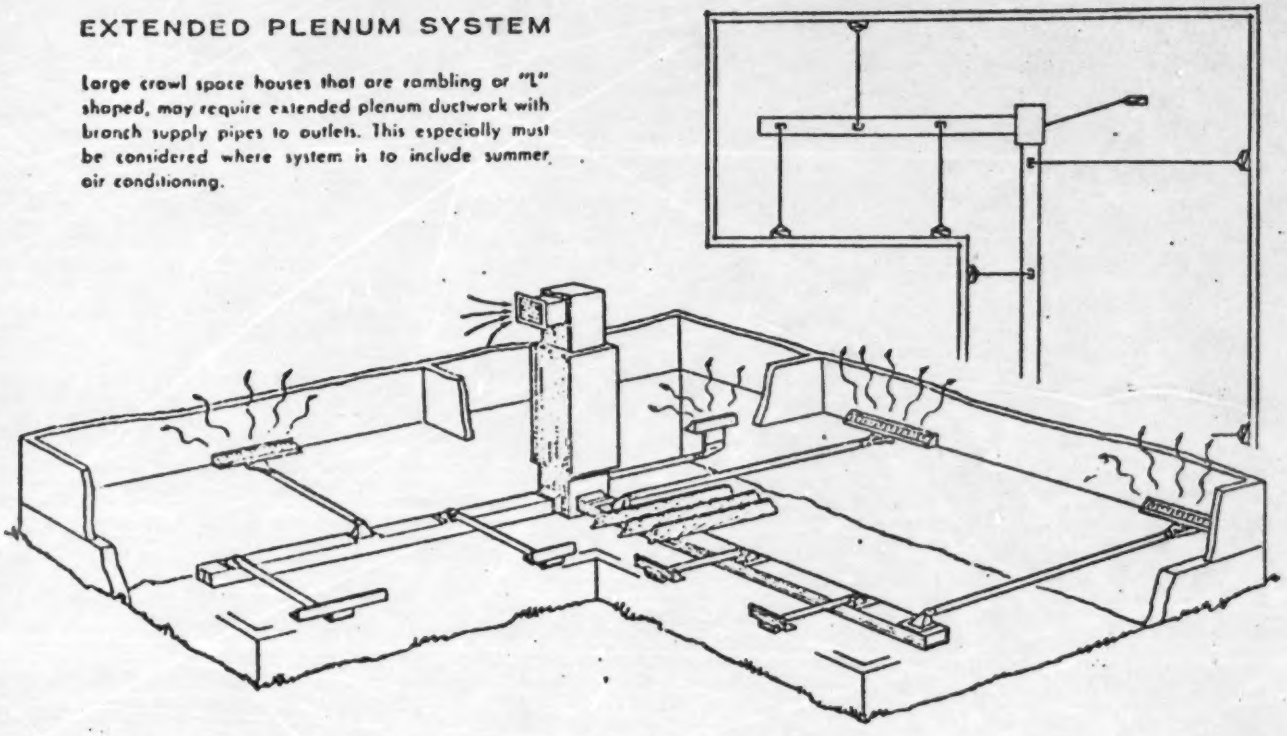
Figure 4.5

EXTENDED PLENUM SYSTEM

Large crawl space houses that are rambling or "L" shaped, may require extended plenum ductwork with branch supply pipes to outlets. This especially must be considered where system is to include summer air conditioning.



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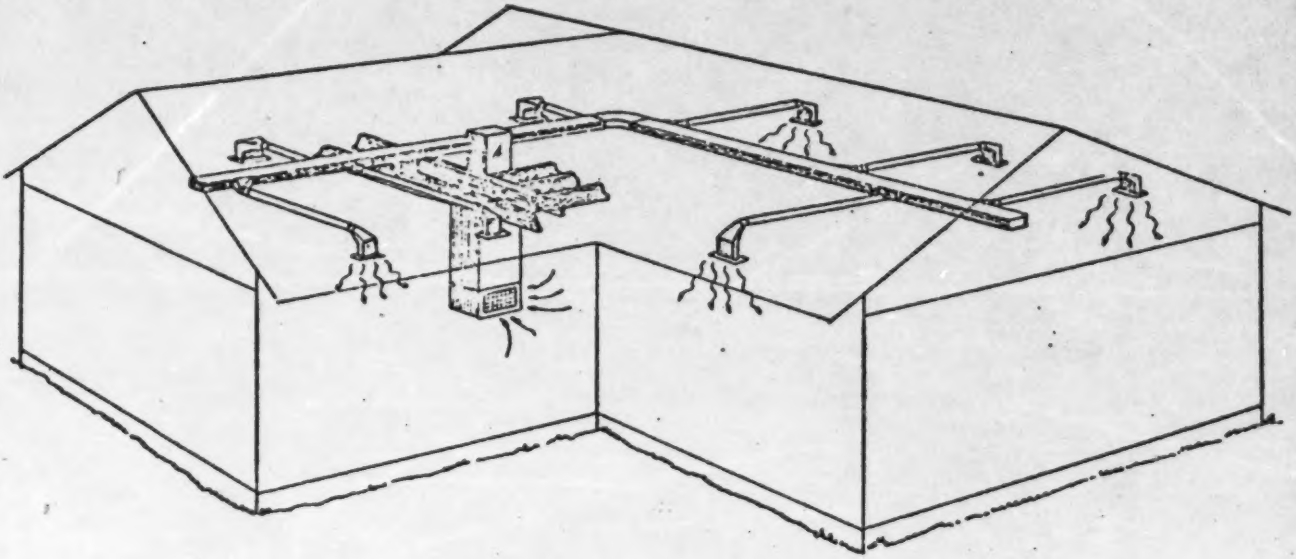
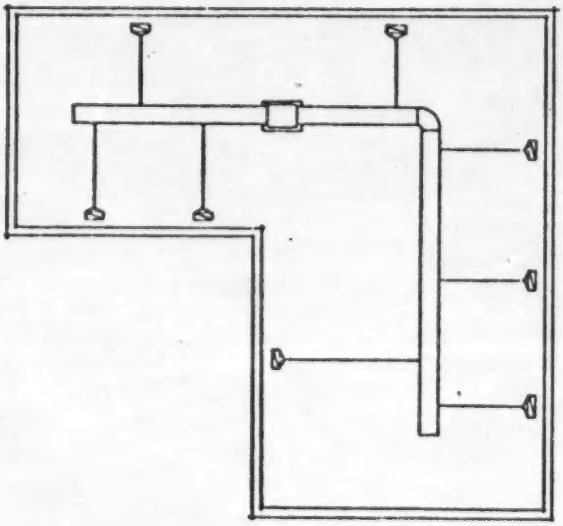
HOUSE ON CONCRETE SLAB
Figure 4.6

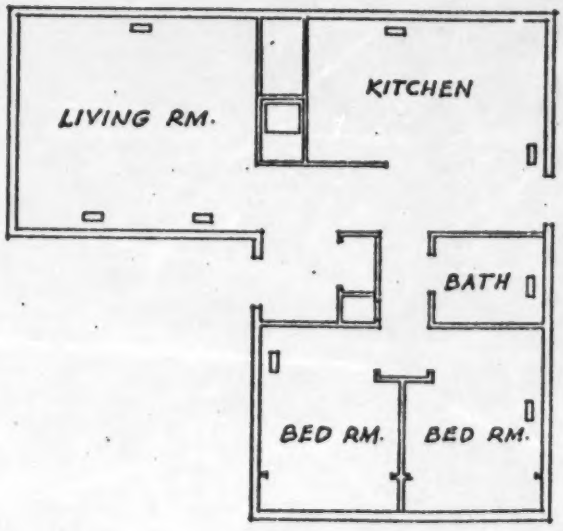
EXTENDED PLENUM IN ATTIC

Unless furnace plenum and supply pipes are cast in the concrete when slab is poured, piping for this type of house must run in the attic. Ducts and piping run across top of joists. Floor diffusers are turned upside down and installed in ceiling near outside walls. Round diffusers centered in room ceilings may be used. Plenum and piping must be insulated.





ATTIC PIPING PLAN



FIRST FLOOR PLAN

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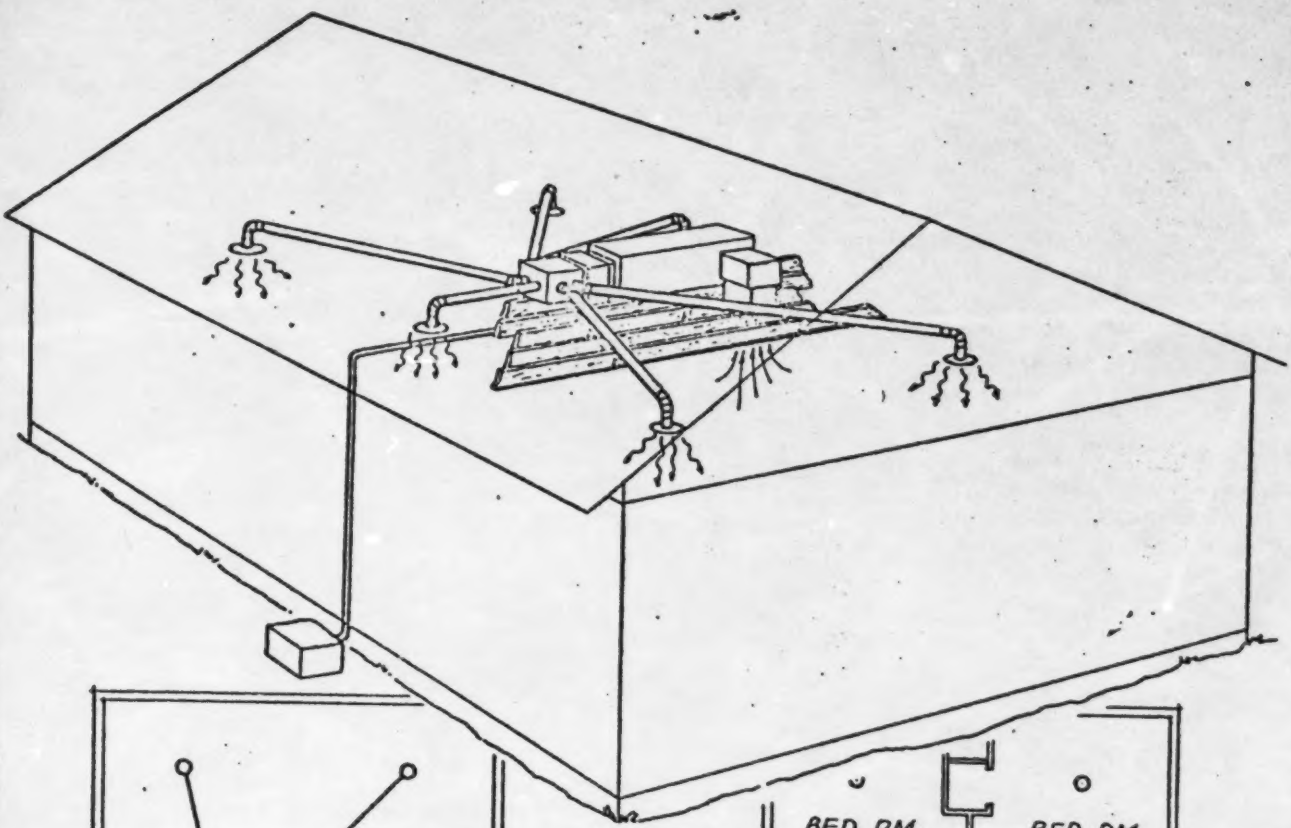
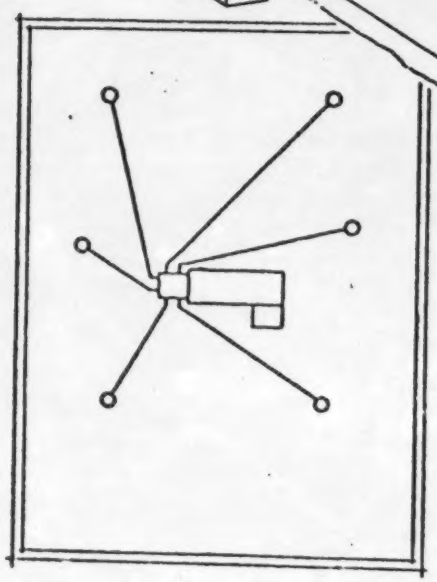
Figure 4.7

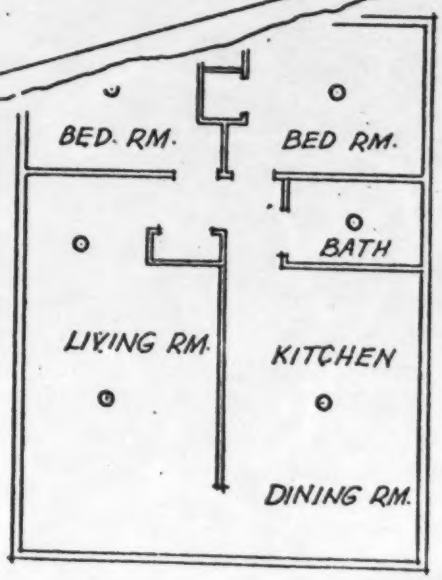
HORIZONTAL FURNACE IN ATTIC

In some installations, a gas horizontal furnace is installed in a properly ventilated attic. Little or no wall cutting is required; diffusers are installed in ceiling; return air grille in ceiling or high wall position. Also an excellent piping system for summer air conditioning. Use extended plenum or radial piping design. Plenums, ducts and pipes must be fully insulated.





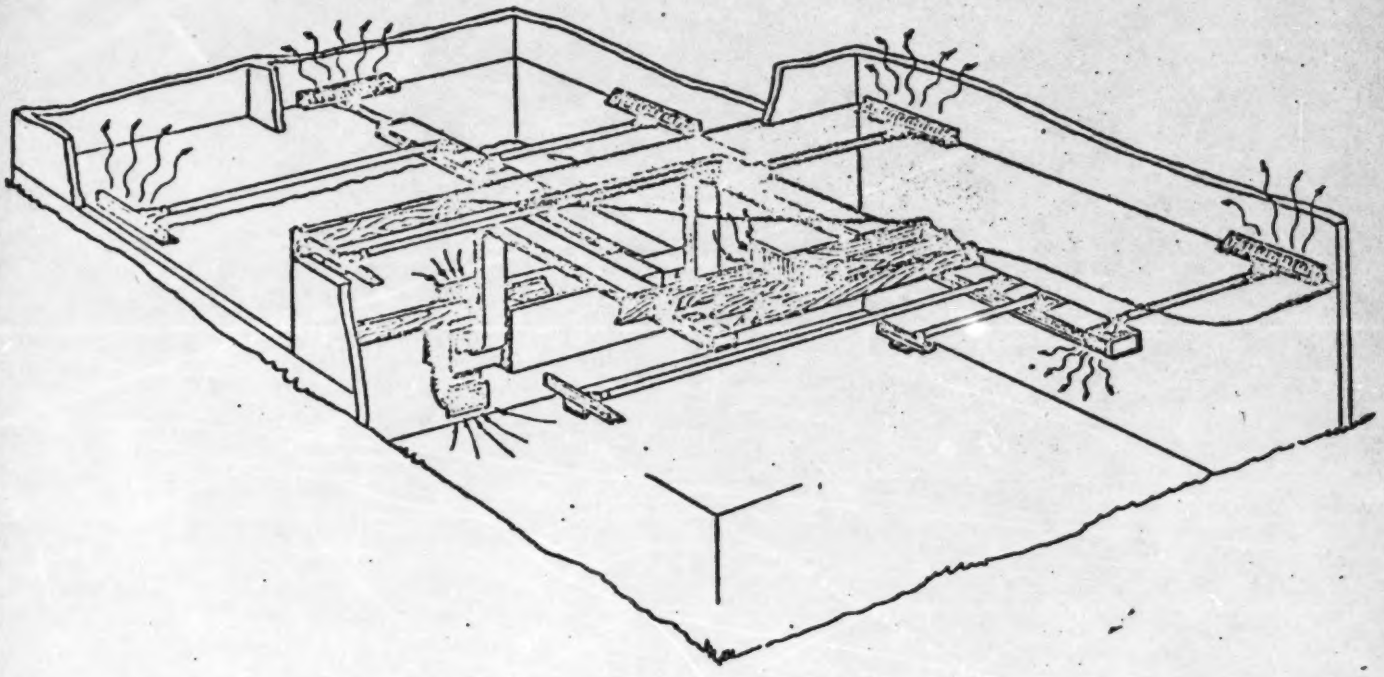
ATTIC PIPING PLAN

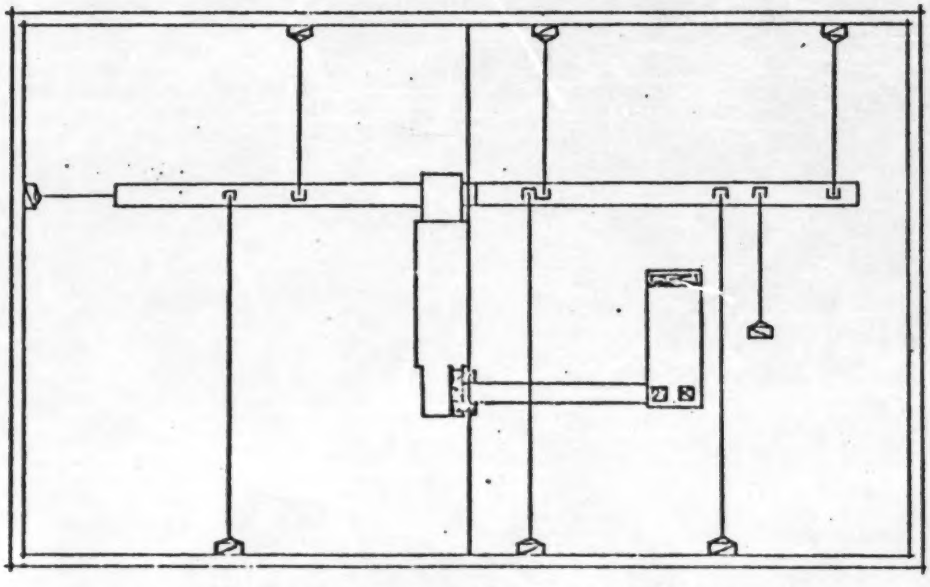


FIRST FLOOR PLAN

SPLIT-LEVEL HOUSES
Figure 4.8

In the illustration shown, a horizontal furnace is suspended from joists under second (ground) level. Ducts are run under floor joists of second and third levels. Branch supply pipes take off from top of ducts and run in joist spaces to baseboard diffusers. A register near end of the supply duct furnishes heat to the first level. Return air grilles are used at each level.





BASEMENT PIPING PLAN

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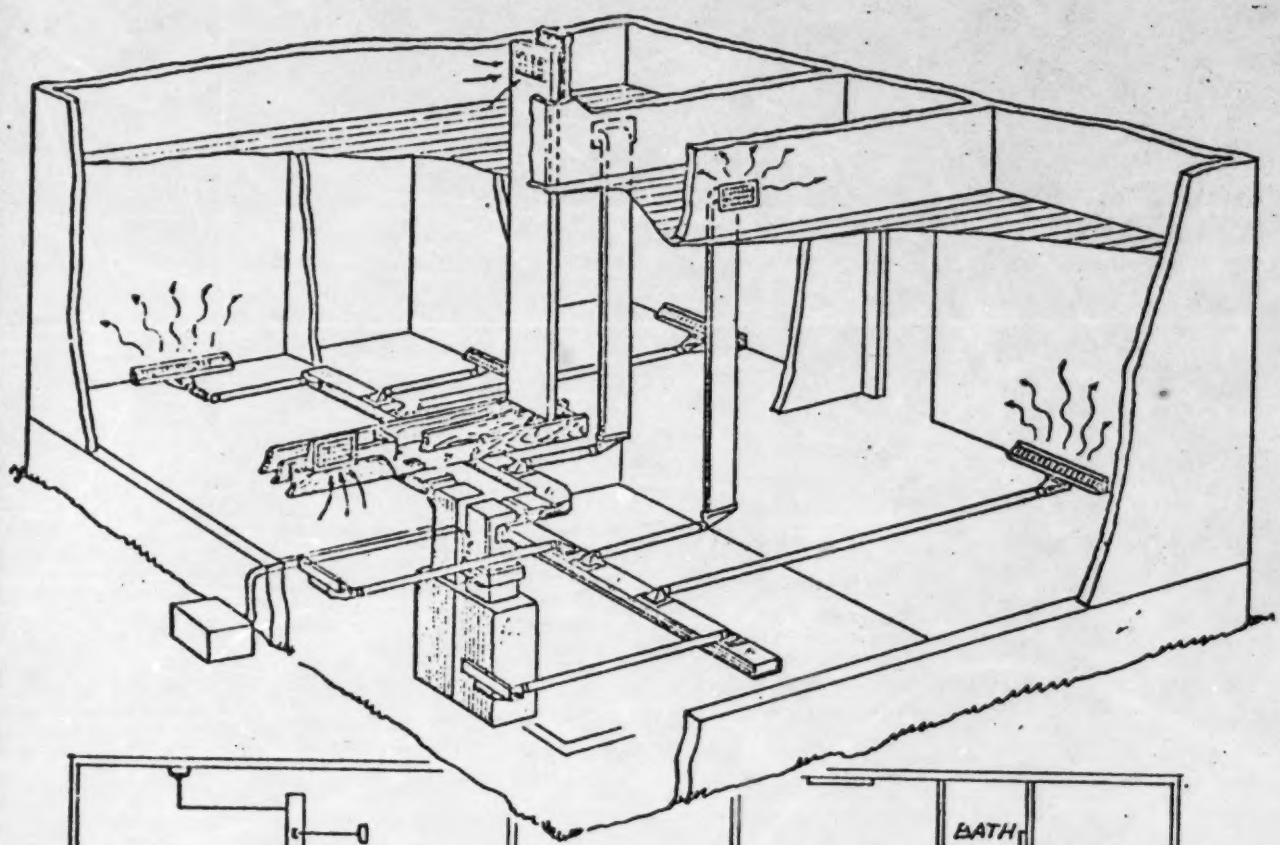
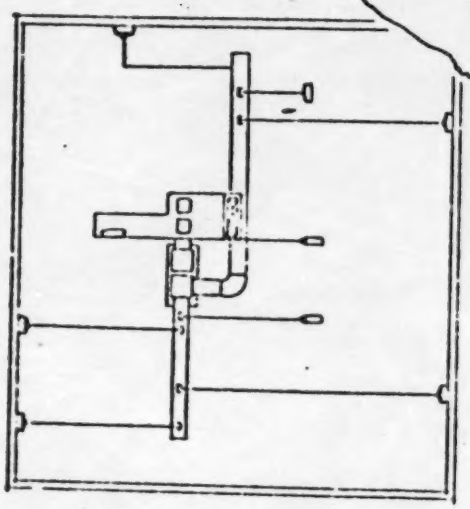
AIR SYSTEMS
TWO-STORY HOUSES

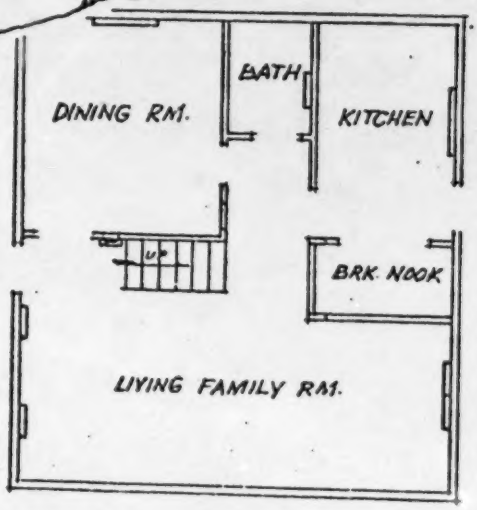
Figure 4.9

A basement lowboy furnace with an upflow cooling coil and outside condenser unit provide year around air conditioning for house shown. Conditioned air is distributed to first floor rooms through baseboard diffusers; second floor rooms are supplied by wall stacks extending through interior and connected to registers. A baseboard grille in downstairs hall and a high-wall grille in second floor collect return air, which drops into sheeted joist spaces.





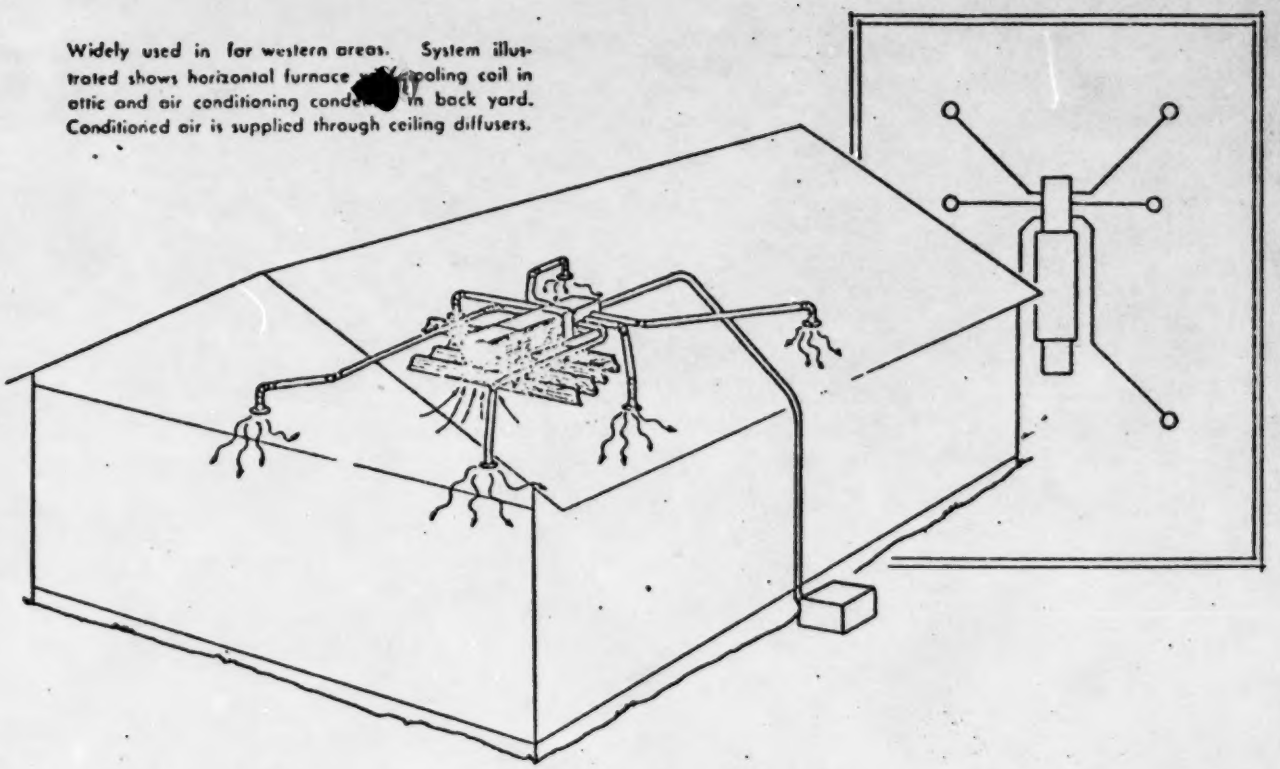
BASEMENT PIPING PLAN



FIRST FLOOR PLAN

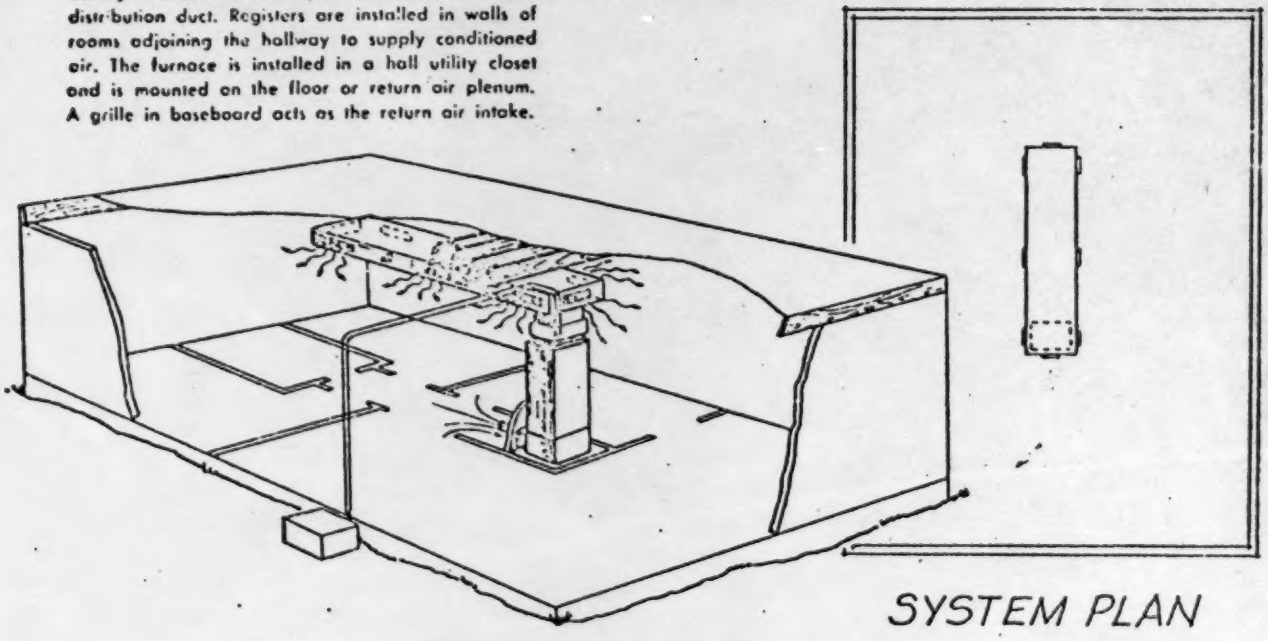
TYPICAL SYSTEMS
WEST PRACTICES
Figure 4.10

Widely used in far western areas. System illustrated shows horizontal furnace with cooling coil in attic and air conditioning condenser in back yard. Conditioned air is supplied through ceiling diffusers.



TYPICAL SYSTEMS
SOUTHWEST PRACTICES
Figure 4.11

In the milder climates of the southwest, a dropped ceiling in a central hallway is often used as a main distribution duct. Registers are installed in walls of rooms adjoining the hallway to supply conditioned air. The furnace is installed in a hall utility closet and is mounted on the floor or return air plenum. A grille in baseboard acts as the return air intake.



SYSTEM PLAN